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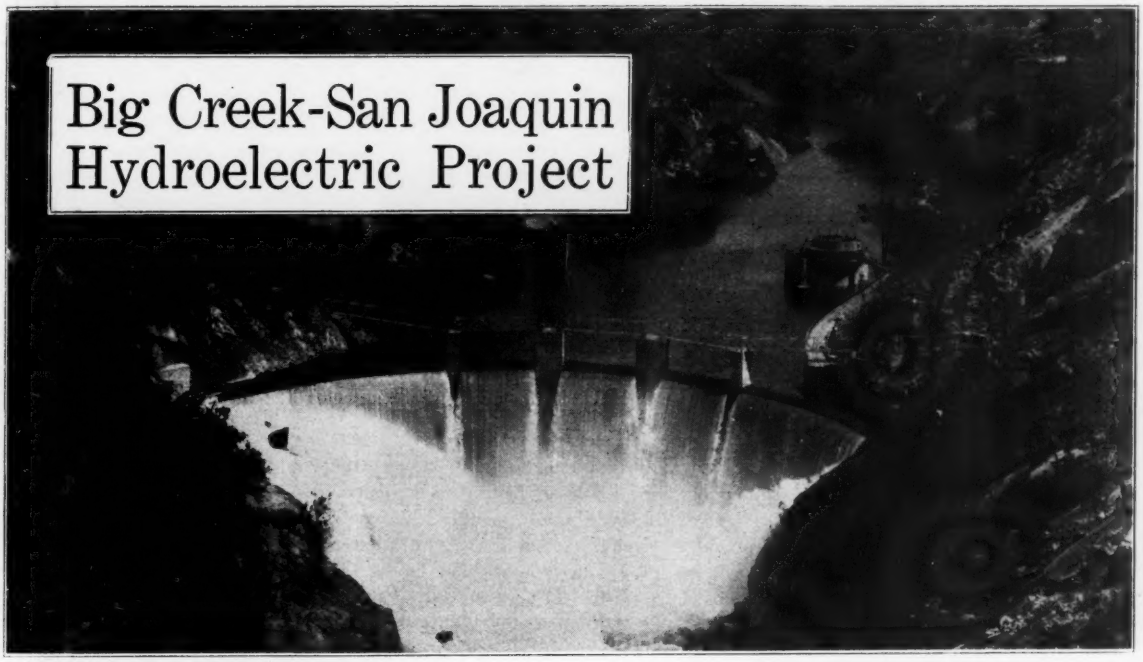

THREE TURBINE UNITS AT THE BIG CREEK NO. 3 PLANT, THE ELECTRIC GIANT DEVELOPS A TOTAL CAPACITY OF 105,000 HP. UNDER A HEAD OF 760 FT. BY CLAUDE C. BROWN

TO SUPPLY adequately the enormous and rapidly increasing demand for electric power in the Southwest, the Southern California Edison Co. is rushing to completion one of the largest and most stupendous hydroelectric power development projects that has ever been attempted. This development consists of harnessing the waters of Big Creek and the upper San Joaquin River, which together with their tributaries drain the entire area from Mt. Hilgard on the crest of the Sierras to the San Joaquin Valley, an area equivalent to that of the Hawaiian Islands; impounding these waters in 12 reservoirs having a total storage capacity of 734,000 area-feet, dropping it through 19 power houses under a total accumulated head of 16,784 ft. and generating an average total of 1,407,000 hp. of hydroelectric energy.

Outstanding features of design such as the head, present and ultimate capacities of the power plants included in the project and also the elevation and storage capacities of the 12 reservoirs in which the water will be impounded are indicated in the accompanying table.

Just below Powerhouse No. 8, Dam No. 6 has just been completed on the main stream of the San Joaquin, a short distance down the stream from the confluence with Big Creek. It has a height of 150 ft. and a crest of 450 ft. From above this dam the waters of Big Creek and the San Joaquin are diverted through a tunnel to supply Powerhouse No. 3, the Electrical Giant.

Energy from this station is supplied to the 220,000-v. transmission line which stretches 270 mi. from Big Creek No. 1 to the Laguna Bell Station in the suburbs of Los Angeles. This is the first 220,000-v. transmission line to be operated in the history of the world, and was first energized at this voltage on May 6, 1923.

BIG CREEK NO. 3, "THE ELECTRIC GIANT"

Big Creek No. 3 plant, known as The Electric Giant, which was placed in operation on October 11 of this year, is the largest capacity hydroelectric plant on the Pacific Coast, having an initial generating capacity of 105,000 hp., which in the ultimate development will be increased to 200,000 hp. This is the fourth hydroelectric generating plant to be completed in the Big Creek-San Joaquin project, and is located on the main stream of the San Joaquin River at a point 7½ mi. below the junction of Big Creek and the San Joaquin.

The diversion dam for Big Creek 3, which is located approximately 6 mi. above the plant, and just below the

junction of the two streams, is a concrete structure with a maximum height from bed rock to crest of 150 ft. and a length of 450 ft. along the crest. It is a simple arch type dam sprung across the canyon to natural granite abutments on either side. For the purpose of controlling the water impounded by this dam, four sluice gates 7 ft. square were installed having a combined discharge capacity of 3000 sec. ft.

At the intake end of the diversion tunnel, just above the dam, is a reinforced concrete intake tower, 115 ft. high. The flow of water into the tunnel is here regulated by an electrically operated cylindrical sluice gate of 22 ft. in diameter and 90 ft. high. The diversion tunnel itself is a 21-ft. diameter bore through solid granite and is unlined throughout with the exception of two or three short stretches where soft ground was encountered and where concrete lining was necessary. This tunnel which is approximately 30,000 ft. in length, from the intake at the diversion dam to the top of the power plant penstocks, has a water carrying capacity of 3000 sec. ft. and was excavated on a grade or slope of 3 ft. to the thousand.

OUTSTANDING CHARACTERISTICS OF THE BIG CREEK-SAN JOAQUIN DEVELOPMENT

		Capacity: hp.	
Powerhouses	Head: ft.	Year 1923	Ultimate
No. 1	2,131	64,300	86,000
No. 2	1,858	64,300	86,000
No. 2-A	2,400		300,000
No. 3	860	100,000	200,000
No. 4	340		67,000
No. 5 and 6	1,480		134,000
No. 7	960		80,000
No. 8	715	30,200	134,000
No. 9 to 15 Group total	3,880		180,000
No. 9, 16, 17, 18 Group total	2,190		133,000
Total		258,800	1,400,000
		Storage: Acre-ft.	
Reservoirs	Elevation	Year 1923	Ultimate
Huntington Lake	6,950	88,000	88,000
Shaver Lake	5,400	6,000	210,000
Florence Lake	7,305		42,000
Blaney Meadows	7,700		23,000
Vermilion	7,625		90,000
Mammoth Pool	3,187		27,000
Chiquito	5,005		80,000
Madera Jackass	7,070		100,000
Forks	9,300		23,000
Paradise Bar	4,530		22,000
Miller's Bridge	4,780		25,000
Junction Butte	4,925		4,000
Total		94,000	734,000

Forebay Manifold

At the plant end, the diversion tunnel terminates in a 200-ft. length of 18-ft. diameter riveted steel pipe which is anchored inside the tunnel mouth and which itself terminates in a steel manifold composed of two large riveted steel plate interconnected spheres. To one of these spheres are connected the 18-ft. diameter tunnel outlet conduit, and two of the 7 ft. 6 in. diameter penstocks, while to the other are connected the four remaining 7 ft. 6. in. diameter penstocks.

This double sphere design forms a forebay manifold of maximum strength and is an ingenious and unique method of distributing the water from the tunnel to the six power plant penstocks. It operates under a total head of approximately 200 ft. and effectively takes care of any excessive stresses.

Each sphere is built of 5/8-in. plates riveted together. The inside diameter of each sphere is 24 ft., and the opening connecting the spheres is 15 ft. in diameter. The opening for the tunnel outlet conduit is 18 ft. in diameter, and the two openings in one sphere and the four in the other for the penstocks are 7 ft. 6 in.

Two difficult parts to fabricate were the flanges for the openings and the reinforcing rings to surround the outstanding legs of the flanges. These immense flanges, each composed of three segments welded together, were shaped by a hydraulic press. Outside of and fitting around the outstanding leg of each flange is a reinforcing ring. These reinforcing rings are made up of five thicknesses of 1-in. steel plates.

Stand Pipes and Surge Chamber

In order to take care of the resultant surges from the 30,000-ft. tunnel in cases of interruption at the plant, a 200-ft. standpipe with a diameter of 3 ft. has been erected at the top of each penstock, the individual standpipes being trussed together to form a tower which is adequately guyed to the granite of the mountain side. At the present time there are three of these standpipes in place, one on each of the three penstocks now in position.

To provide further against any possible disastrous effects of such surges, a unique and novel type of surge chamber was blasted out of the solid granite, at a point far enough back along the tunnel line to give a height of 200 ft. from the surface of the mountain side to the tunnel center. This surge chamber is in the shape of a huge hour glass, 200 ft. high, 75 ft. in diameter at the top and bottom, 25 ft. at the central restriction. The hour glass shape was adopted on account of the wide variation in the water level behind Dam No. 6 at the tunnel intake which takes place under normal operating conditions. The large section of the chamber at the bottom takes care of a suddenly applied load at Big Creek No. 3, in which case it acts as a storage chamber and furnishes the water for the sudden demand. The upper portion of the chamber takes care of the surge resulting from rejected loads, producing the cushioning effect to dissipate the surge. The narrow neck in the center acts as a sort of baffle or restriction which dampens the severity of the surge. This surge chamber which is known on the project as "King Tut's Tomb," is probably the most unique design of chamber for this purpose in existence.

At the present time, three of the ultimate six penstocks, one for the purpose of supplying each turbine, are in place. These penstocks are made entirely of forge welded steel pipe varying from 7 ft. 6 in. in diameter at the forebay to 6 ft. in diameter at the plant. The ends of the sections making up the pipe are bumped and belled just back of the line of rivets of each circumferential seam so that the rivets are at an angle with the perpendicular to the axis of the pipe. Being located in this way, the section of the rivets over which the shear stresses are distributed, instead of being a circular, right section of the rivet, becomes an oval section of greater area. This materially reduces the unit stress due to shear in the rivet shank.

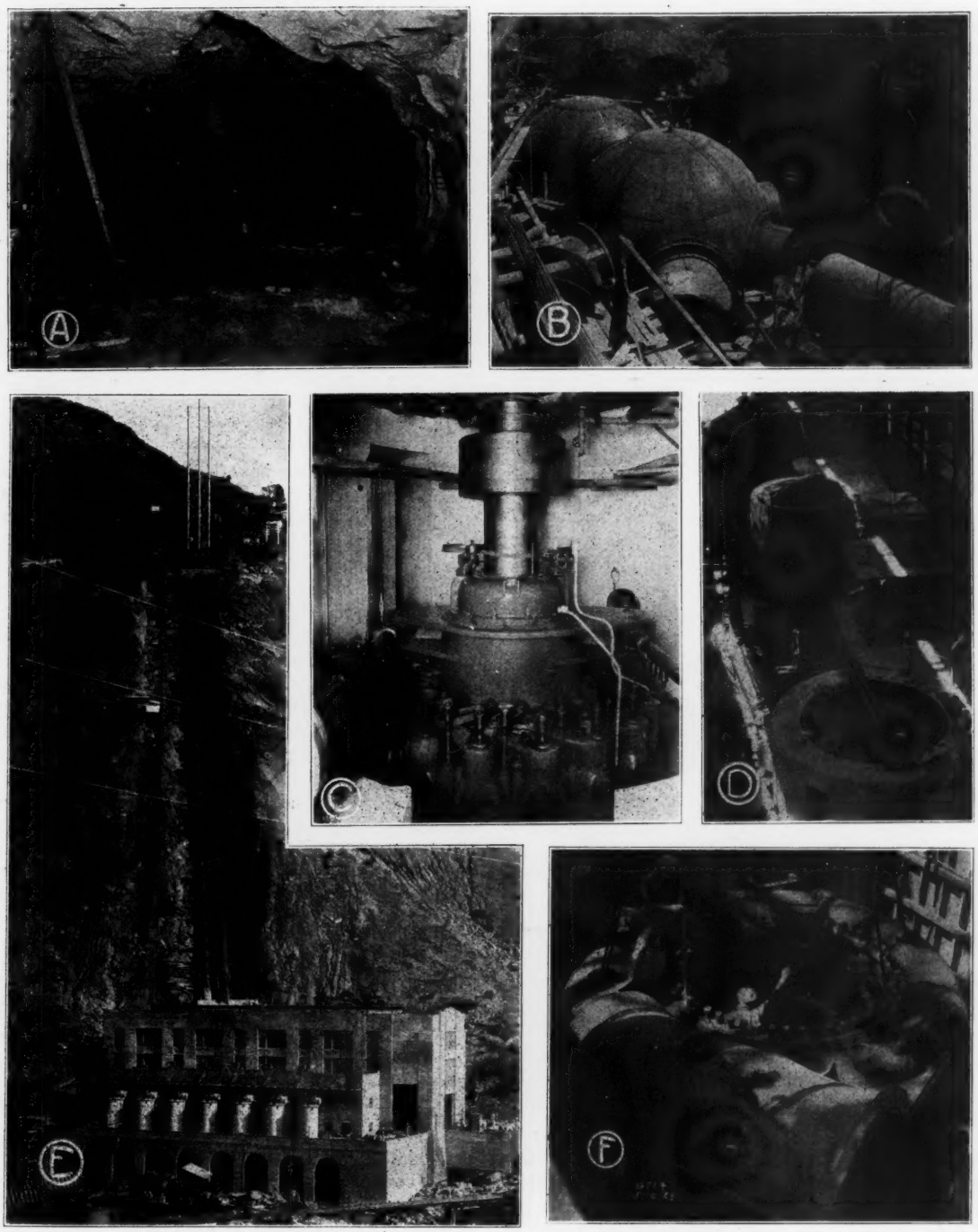

FIG. 1. HYDRAULIC EQUIPMENT AT BIG CREEK NO. 3

A. Base of hour-glass surge chamber cut out of solid granite in the mountain side above the plant.

B. Two spherical steel manifolds distributing water to six penstocks of which three are installed.

C. Turbine gate operating mechanism.

D. View of generator room showing base ring set for generators. Three units are now installed.

E. Three penstocks are now in place.

F. Scroll case for vertical Francis type high head turbine to operate under a head of 760 ft.

As the penstocks are laid above ground, it was necessary to install expansion joints between anchors. These expansion joints consist of packed slip joints, the portion of the pipe against which the packing slides, being copper plated with a thickness of $\frac{1}{16}$ in. of copper, the purpose of which is to insure a smooth and non-corroding joint which will give a minimum amount of trouble and leakage.

Utilization of this type of penstock construction produces considerable friction on the supporting piers which makes it essential that heavy and adequate anchors be provided at the bends in the pipe. For the purpose of reducing the size of these anchors to a minimum, facilitating the erecting of the penstocks and relieving the pipe of excessive longitudinal stresses, the pipes were installed on cast iron rockers. These rockers are installed at intervals of 40 ft. instead of the usual 20-ft. interval used with the ordinary concrete piers. Due to the use of these cast iron rockers, the friction between the pipe lines and the supporting piers has been reduced to such an extent that a material saving was accomplished in the cost of supporting piers and anchors.

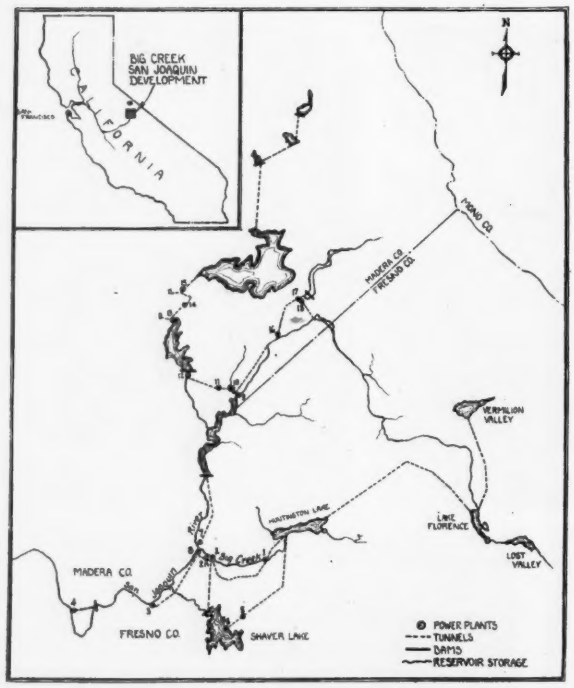

FIG. 3. BIG CREEK-SAN JOAQUIN PROJECT TAPS A WATERSHED EQUIVALENT IN AREA TO THE HAWAIIAN ISLANDS

For the control of the flow of water in these penstocks, there are installed at the upper end, 7½-ft. diameter butterfly valves in each line, arranged for remote electric control from the power house below. At the lower end of each penstock, flow control is effected by a needle type control valve.

For the purpose of keeping a record of the water flow, the Southern California Edison Co. is installing venturi meters in all of its hydroelectric power plants. The tubes of these meters are installed in the penstocks which supply the water to each unit and the registering and recording apparatus is located on the generator control board.

There is a great deal of importance and value attached to the utilization of a reliable meter for the measurement of rate and quantity of water supplied to each unit. Where these meters are installed their use becomes invaluable, not only for the purpose of enabling the plant operators to obtain the maximum possible capacity from the amount of water available but also as a continuous check upon the efficiency of the generating apparatus. The officials of the company state that some recent tests on one of the impulse units in one of the plants, showed that the difference in output between a new nozzle and a nozzle that had been slightly worn from a period of continuous usage, amounted to something over $1000 per month in revenue return, which was several times the amount that would have been necessary to replace the worn nozzle.

Venturi meters have been installed on each of the three units now in place in the Big Creek No. 3 plant, and the same type of meters will be installed on the three future units when the latter are put in.

Power Plant Structure

Excavation for the powerhouse structure at Big Creek No. 3, was started in June, 1922, and the first concrete was poured in January, 1923. This excavation was carried on by means of blasting, hydraulic sluicing and steam shovel work and consisted in clearing a space for a portion of the structure out of the solid granite of the mountain side. The power plant building is of reinforced concrete, 200 ft. long, 139 ft. wide and 110 ft. high from the tail race floor to the structural steel roof. One end of the structure is sealed with corrugated galvanized iron which will be removed when the building is doubled in size for the ultimate installation. The generating room, which contains the prime movers, is 55 ft. wide by 70 ft. high and is well lighted and ventilated.

As the plant is laid out, the operating floor is on two levels, one at the base of the generators and the other at the elevation of the turbines. This arrangement eliminates the generating room basement and enables the operators on watch to have a full view of practically all of the equipment at one time.

Prime Movers

At the present time, the initial installation of prime movers in this plant consists of three 35,000-hp. vertical Francis type turbine built by the Wellman-Seaver-Morgan Co. These turbines operate at a speed of 423 r.p.m. under a 760-ft. head and are equipped with Woodward governing mechanism. The design is so arranged that the upward and downward thrust of the impeller is nearly equal, the resulting thrust being taken care of by a Kingsbury thrust bearing.

The generators of these units are rated at 25,000 kv.a., 11,000 v., 50 cycles, are of Westinghouse design and are equipped with direct connected exciters. The entire generator is covered with a sheet iron dust and water-proof ventilating housing provided with ventilating duct and fan.

Each generating unit is equipped with its own lubricating system independent of the other units, thus eliminating the usual exterior lubricating oil system, with its filters, supply tanks, pumps, piping, etc. Experience has shown that the best results are obtained by simplifying the lubricating oil system to the greatest feasible extent. The main bearings on the water wheel and on the generator are provided with gear driven oil pumps which pump the

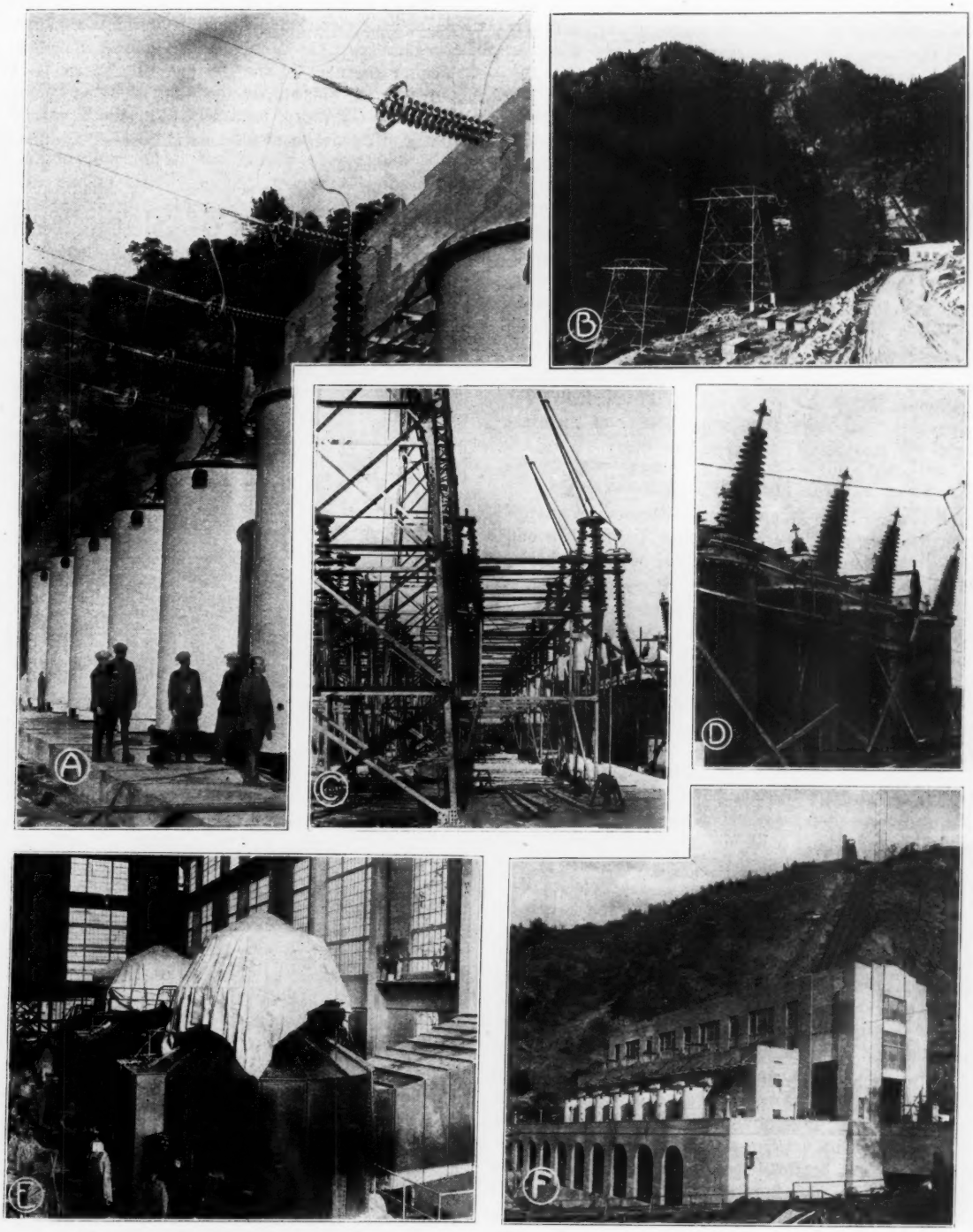

FIG. 2. ELECTRICAL EQUIPMENT AT THE "ELECTRIC GIANT"

A. Seven 11,000-220,000-v. single phase transformers step up the energy for transmission.
B. Big Creek 220,000-v. transmission line.
C. High potential disconnect switches.
D. High tension oil switches are in duplicate.
E. Interior view showing generators in place.
F. Big Creek No. 3 power house showing high tension transformers. One is a spare unit.

lubricating oil from a small sump below the bearings to the top of the bearings thus setting up a positive and continuous circulation of oil. Motor driven pumps are also installed that cut in service automatically in case the gear driven pumps should fail.

Draft tubes of the turbines in this plant consist of a modifed spreading type of tube which is supposed to embody the advantages of the regular spreading type but is somewhat simpler in construction. Due to the fact that the Edison plants are all high head plants, the additional efficiency obtained through the use of theoretically perfect draft tubes over those of simpler design does not warrant the additional effort and expense necessary in the construction of the former.

Energy from the generating units of this plant is conducted to an 11,000-v. bus through standard switching equipment. Also connected to this bus and located on the top of an especially constructed concrete platform are seven Westinghouse 17,500-k.v.a., 50-cycle, 11,000/220,000-v. single-phase outdoor type transformers. Six of these are in service, the remaining unit serves as a spare.

High Tension Switching Apparatus

High tension leads from the transformers are carried on steel towers across the canyon to the "garden," or outdoor high tension switching station. The switching station is 195 ft. in width and 430 ft. long. It consists of a series of concrete benches or terraces excavated on the slope of the mountain, with a difference of elevation of 46 ft. between the upper and lower benches. Upon the benches or terraces are erected the oil switches, disconnecting switches, frames and insulated piers for carrying the high tension bus structure.

This switching station consists of duplicate sets of bus bars, sectionalizing switches, disconnects, and oil circuit breakers by means of which the power can be routed in a number of different combinations of routes. The 220,000-v. bus structure consists of a highly insulated framework of 4-in. galvanized iron pipe covered with two coats of red lead. All of the joints in this structure are welded. The high tension leads from the power plant to the switching station and also the high tension transmission lines are of aluminum cable approximately 1⅛ in. in diameter.

Power generated at Big Creek No. 3 will be spread over the entire system of the Edison Co. by means of some 275 mi. of transmission lines and will be used in some 300 towns, cities and rural communities in Southern and Central California. This quantity of power is sufficient to take care of the electrical requirements of the consumers in a city with a population of approximately 1,000,000 people.

While 105,000 hp. is 15 per cent larger than any other hydroelectric plant on the Pacific Coast, the new Electric Giant is susceptible of being doubled in capacity when the great Florence Lake tunnel, the longest water tunnel in the world, is completed some two years hence. It is this great tunnel, driven through solid granite, that is attracting the attention of the engineering profession, as it is one of the outstanding features of the Big Creek-San Joaquin project. Nearly a mile in elevation, above the site of the Electric Giant the construction army is now working on the Florence Lake tunnel which is nearly 14 mi. in length and which will tap the enormous watersheds which lie beyond one of the main ridges of the Sierra Mountains. This tunnel will be more than twice as long as the Rogers Pass tunnel on the Canadian Pacific Railway, which is at present the longest on the American continent, and it will be more than a mile longer that the Simplon tunnel through the Alps of Switzerland, which, pending the completion of the Florence Lake tunnel, is the longest in the world.

Acknowledgment of the courtesy of Charles H. Peirson, Supervisor of Information, and of other officials of the Southern California Edison Co., is made by the writer, for much of the data and information used in the preparation of this article.

Pulling Power of Slack Belts

By W. F. Schaphorst

THERE has always been some question in the minds of many belt users regarding the pulling power of slack belts. Many belt men, even engineers, think that a slack belt cannot pull as heavy a load as can a tight belt.

Out of curiosity therefore, and for the purpose of setting at rest the minds of those who might be opposed of slack belts, I have checked over data on a number of actual slack belt drives and am giving the results in the table below covering all of the slack belts on which figures were procurable, namely, eleven leather belts, two gandy belts and three cotton belts.

Table

Width, Inches	Thickness	Kind of Belt	Total Hp.	Belt Speed ft. per min.	Total Pull lb.	Pull per in. of width, lb.
		Leather				
20	3-ply	Leather	100	1410	2340	117
14	——	Leather	100	2090	1580	113
14	2-ply	Leather	125	4330	952	68
19	2-ply	Leather	90	1412	2100	110
6	2-ply	Leather	25	1200	688	114
14	2-ply	Leather	35	1140	1010	72.3
8	single	Leather	20	1350	489	61.2
12	Laminated	Leather	82	2500	1110	92.6
16	2-ply	Leather	100	3060	1078	67.5
12	2-ply	Leather	70	5300	435	36.2
10	2-ply	Leather	35	2540	455	45.5
		Gandy				
16	——	Gandy	300	2340	4230	264
12	——	Gandy	50	3770	438	36.5
		Cotton				
12	6-ply	Cotton	75	3360	735	61.2
10	——	Cotton	70	1810	1275	127
10	——	Canvas	85	3110	900	90

I will admit that I myself was amazed to find in one instance that with a gandy belt the pull per inch of width runs up to 264 lb. For a leather belt the highest pull per inch of width is 117 lb. and for a cotton belt 127 lb. This, of course, does not mean that the ratios of pulling power of these respective belts are 264, 117, and 127. I believe that these "happened" to be the loads and that they could be interchanged if necessary without difficulty. I have much faith in the slack belt when operated under proper conditions. One of the leather belts, as will be noticed, is a laminated belt.

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British Developments in Water Tube Boilers

NEW DESIGNS PROVIDE FOR INDEPENDENT CIRCULATION OF WATER IN TUBES NEAREST THE FUEL BED. BY F. JOHNSTONE-TAYLOR

SINCE THE introduction of the Babcock boiler in England, water-tube boilers have had a continued period of popularity, Lancashire and other fire-tube types being now mainly confined to the smaller plants and the production of steam at moderate pressures, except when there is otherwise definite reason for their installation.

Considerations of space, however, especially with units having large steaming capacity, have given an impetus towards the development of one or two other designs of water-tube boilers, among which the "Clayton" is a design which is receiving a great deal of attention. It is a boiler of the multi-drum type, and is so designed as to provide for the utmost rapidity of circulation, upon which, as is well known, the rate of heat transmission primarily depends. For this reason, in any boiler it is of the utmost importance to secure the maximum and unimpeded water circulation through the three rows of tubes nearest the fire, these being considered as actually performing anything up to 75 per cent of the total evaporation.

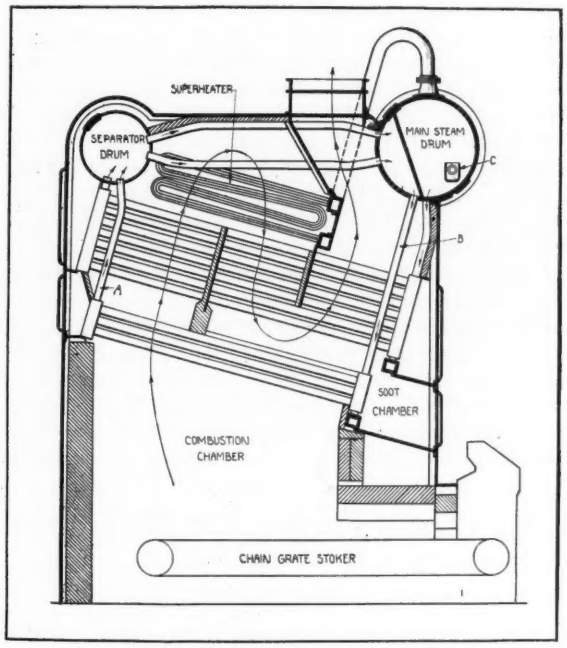


FIG. 1. IN THIS BOILER, INDEPENDENT CIRCULATION OF WATER IS PROVIDED FOR IN THE THREE LOWER ROWS OF TUBES

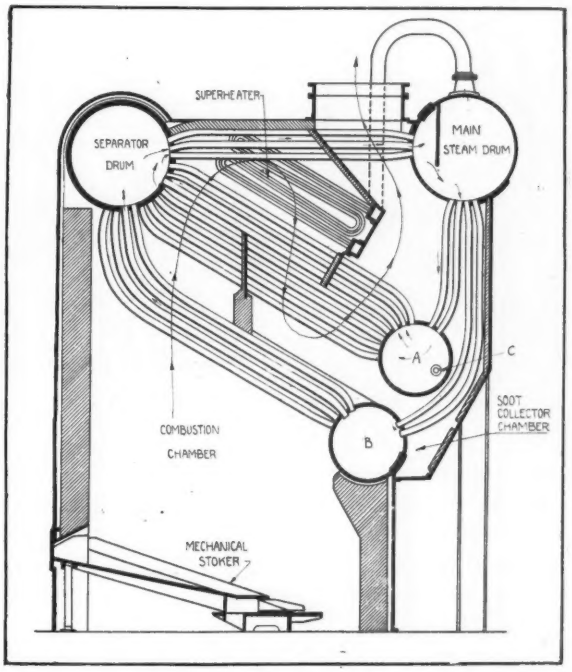


FIG. 2. A MULTI-DRUM BOILER USING THE SAME PRINCIPLE OF CIRCULATION AS THE TYPE SHOWN IN FIG. 1

CONSTRUCTIONAL FEATURES

In the boiler illustrated in Fig. 1, this circulation is effected by providing independent circulation in the large rows of tubes immediately above the furnace which are connected to the drums by straight heaters of ample cross-sectional area. The constructional features of this boiler are apparent from the drawing. It consists of two drums, the main steam drum and a separator drum arranged crosswise, as shown. Two independent circulating paths are provided, first, the rows of tubes immediately adjacent to the fuel bed already referred to, and second, the main bank of tubes, through which the circulation is slower. The superheater is placed in the space between the upper row of tubes and the drums.

Another type of boiler employing the same principle, but of the multi-drum design and having direct connected tubes, is shown in Fig. 2. This is a type of boiler now especially in favor, the necessity for headers with their numerous hand holes not being regarded as essential in well organized power stations in view of the fact that pure feed water is regarded in itself as an essential to a modern boiler plant. Elaborate apparatus, such as evaporators and deaerators, are often provided to insure pure feed water.

In both Figs. 1 and 2 it will be observed that the lowermost tubes are arranged for rapid circulation. They are provided with separate downcomers and separate outlets. In the case of the header type, the density of the rising column "a" is much less than could be possibly obtained by employing only one header, while the momentum of the solid water column in "b" acts as a powerful driving force, producing acceleration in the lower tubes. In addition, by dividing the headers into two sections the difference of expansion in the upper and lower tubes is provided for.

It is evident that the separating drum acts as a stabilizer to prevent priming. The point "c" of the introduction of the feed should be noted. It enables

the water to circulate through the upper tubes before reaching the lower ones, thus any deposit having a tendency to form does so, not in the lower hot tubes, but in the upper ones which are of necessity cooler while the water flowing into the furnace tubes is at full boiler temperature and ready to absorb latent heat, permitting of the most rapid heat absorption therein.

Exactly the same principle is provided for in the design shown in Fig. 2. The feed inlet at "c" causes the water to circulate first through the upper tubes. The provision of two water drums "a" and "b" provides for difference of expansion between the two groups of tubes. It is interesting to note that these boilers which are built in units having a capacity of

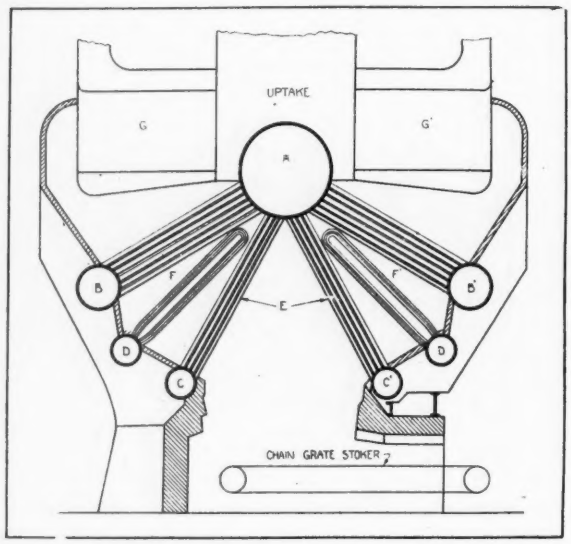


FIG. 3. THE YARROW BOILER FOR STATIONARY SERVICE

100,000 lb. of steam per hr. and over have no transverse joints in the drums, the plates being rolled in one piece.

The Yarrow Type

This design of high duty boiler is at the instance of a firm, who for some 40 yr. have specialized in boilers for high speed steamers, although they have from time to time produced land units of considerable size. One of the main features is the ample provision for access and examination of the straight generating tubes and the minimum number of inspection doors; the only joints in the design, apart from boiler mountings, are the manholes at each end of the steam drums and water collector. By reference to Fig. 3, showing the boiler in section, it will be seen that the tubes are arranged to give the most rapid circulation so as to be able to cope with sudden and high overload while the very large radiating surface and the provision of air heaters as an integral part of the unit should be noted. The main steam drum A is 60 in. in diameter, the two water drums B-B′ being 30 in., the other two C-C′ being 23 in. The superheater drums D-D′ are also 23 in. in dia. The unit shown has an evaporative surface of 9100 sq. ft., of which tube nests "E" account for 2135 sq. ft. As regards superheaters F-F′, these are composed of 1⅛-in. U-tubes expanded and bell mouthed into drums D-D′. The units are self draining and the steam makes two passages through each part in series. The boiler shown is arranged for coal firing, having two chain grate stokers 8 ft. wide with a total area of 220 sq. ft., but other designs provide for the use of pulverized fuel and oil. The air heaters G-G′ placed in the uptake are of the tubular type containing 1504 tubes 2¾ in. diameter and 8 ft. in length, the hot gases from the furnace passing through the inside of the tubes.

After leaving the heater the hot air passes over the boiler casings, absorbing further heat and reducing radiation losses. A point of interest is the drilling of the water drums in such a way that all the tubes, even the outside rows, enter it straight so as to enable the expanding and bell mouthing to be done so as to ensure absolute tightness, an arrangement which has been adopted by the builders for many years.

These boilers are built in a somewhat modified form to suit a wide variety of conditions. Some are built with one superheater element only, while the air heaters are placed in some cases diagonally in the uptake, making a very compact unit. A boiler of the type shown in Fig. 3, rated at 64,000 lb. of steam at and from 212 deg. F. gave an efficiency under observed test of 86 per cent, feed being supplied at 80 deg. F. and steam generated at 215 lb. pressure and 330 deg. superheat. The analysis of flue gases showed a percentage of CO_2 of 12½ per cent.

Careful temperature tests showed a considerable drop thereof in the furnace gases immediately after passing the first three rows of tubes, showing agreement with the contention previously made that these tubes form a big percentage of the total evaporation. Boilers of this design are usually arranged for a combination of forced and induced (balanced) draft under which conditions the highest possible efficiency is obtainable.

Arguments For the Use of Oil Fuel

Advantages of oil as a fuel over coal are:

a. Handling cost is low due to ease of handling and storage.
b. General labor, such as stoking, coal passing, etc., is saved.
c. Storage can be at greater distance from boilers; oil occupies 50 per cent less space, and has 25 per cent less weight than coal for equal heat values.
d. More perfect combustion is obtainable; there is no loss due to ash and small coal in ash, no clinker; air can be more correctly controlled.
e. Smoke can be entirely eliminated.
f. Intensity of the fires can be instantly regulated to meet fluctuating loads and steam demands. No pulling of fires is necessary.
g. No loss in calorific value or disintegration in storage.
h. No loss from powdering or dust.
i. No necessity for screening as with coal.
j. The pumping of oil does not wear out the machinery as does the conveying and crushing of coal.
k. Smaller stack and lower drafts are required for oil than for coal.
l. No loss from banked fires.
m. Tests have shown that under the same average steaming conditions, oil will give 4 per cent higher net overall efficiency than will coal.

Measuring Oil Burner Steam Consumption

ORIFICE MANIFOLD FOR MEASURING STEAM CONSUMPTION CAN EASILY BE MADE IN THE PLANT. BY FRANK A. ROTHWELL

WITH the operation of an oil-burning installation comes the desire to know how much of the total steam developed is consumed in atomizing the fuel. This steam consumption can, and frequently does, run into large proportions where no check or demand is made for atomizing efficiency. It merits a burner manufacturer very little to state that his burner uses less steam per pound of fuel than any other burner if the firemen operate their steam valves wide open irrespective of the amount of fuel being fired.

Over atomization has somewhat the same effect as under atomization. Under atomization causes smoke which can be seen and is a sure mark of the inattention of the fireman. Over atomization cannot be determined by vision, it can partially by sound but to no accurate extent. The exact loss of over atomization can only be determined by knowing how much excess water vapor is being admitted into the furnace. The effect of steam upon fire is too well known to merit lengthy discussion here. Needless to say, however, for every extra pound of water vapor admitted into the furnace over that required to atomize the fuel diminishes your efficiency a certain per cent and as that excess increases your efficiency increases.

In the larger plants provision is almost always made for the installation of flow meters on lines leading to steam consuming units. In the small or medium sized plant the expense involved in placing flow meters on auxiliary units is almost prohibitive.

Most plants that run engines of the Corliss type, or like principle, possess a steam engine indicator. This instrument serves well the purpose of determining the water rate of these engines as well as also determining the water rate of duplex pumps. If by chance there is some plant which does not possess any means for determining the water rate of any of the auxiliary units the method herein described is suitable for anything that consumes steam.

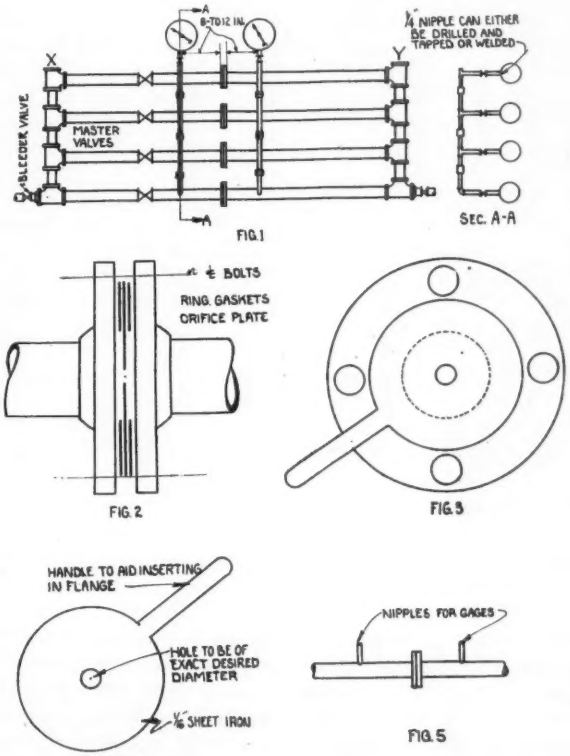
This discussion will deal solely with the measurement of steam for fuel atomization nevertheless the same principles can be adapted to any other unit.

ORIFICE MANIFOLD FOR MEASURING STEAM

For the operator who desires a real knowledge of the operating efficiency of his burners, and has not the necessary equipment to gather the required data, the orifice manifold will answer his needs admirably. This manifold is constructed of common every day pipe fittings and is worth several times the trouble and expense necessary to construct. For the average work to be done a manifold made of 2-in. stock is sufficient. This manifold requires no upkeep, is simple to operate, easy to install and lasts a lifetime. This manifold is outlined in Fig. 1. Figures 2, 3 and 4 give the details of inserting the plates in the flanges. The only measurement to be rigidly adhered to is the length of the 2-in. nipples on either side of the flanges. For the inlet side the distance from the master valve to the flange should be 16 in. and on the outlet side from the flange to the tee should be 24 in. The rest of the manifold can be made up to suit.

There are placed between the four flanges in the manifold four orifice plates. These plates are of $\frac{1}{16}$-in. sheet iron and are cut to fit the inside diameter of the flange bolt holes as shown in Fig. 3. In the center of each plate is a hole of desired diameter. It is absolutely essential and important that the holes made in the center of the plates be exactly the same diameter as the dimensions used in the calculation. This feature must not deviate or the results obtained will be in error.

The principle of the manifold is the flow of steam from a higher to a lower pressure where the lower pressure is not less than 58 per cent of the absolute initial



DETAILS AND ASSEMBLY OF ORIFICE MANIFOLD

Fig. 1. Diagram of Assembled Manifold. Fig. 2. Plates, Ring Gaskets and Flange Assembled. Fig. 3. Detail of Orifice Plate Installation. Fig. 4. Orifice Plate. Fig. 5. Permanent Orifice in Line.

pressure. It is well to explain this statement since the values shown in the accompanying table are based on that figure. The flow of steam from a higher to a lower pressure increases as the drop in pressure increases to where the lower pressure is 58 per cent of the absolute initial pressure. Below this point of 58 per cent the steam flow neither increases nor decreases even though the drop in pressure extends to a perfect vacuum.

Data given in the table shown are based on 50 per cent of the permitted drop to 58 per cent. For example if the drop to 58 per cent were 42 lb. the values as shown were based on 50 per cent of that or only a drop of 21 lb. This is done in order that no errors may arise from selecting plates whose capacity would be too small thereby giving a drop to a pressure below 58 per cent.

From the outline of the manifold in Fig. 1 you will see that the pressures are taken with pressure gages that are attached to each side of the orifice plate. The manifold connecting the gages with each plate is so constructed that it permits readings on each individual orifice. With the master valves and gages constructed so, it is possible to use only one orifice if so desired.

For the four orifice plates a convenient and most generally used orifice plate assembly is 1 in., ¾ in., ⅝ in. and ½ in. An assembly of this nature permits of a large range of capacities. By closing the master valves as shown, the manifold can be reduced to one plate of ½-in. As shown by the table at 30 lb. and with the calculated drop this orifice has a capacity of 3.32 lb. of steam per minute while the combined capacity of all the plates at 100 lb. is 94.19 lb. of steam per min. This range of capacity will be sufficient for almost every burner line need. If, however, it is desired to conduct tests on one individual burner you will find that plates of ⅛-in., ¼-in. and ⅜-in. are best suited for single burner work.

In the mechanical operation of the manifold, the steam flows into the manifold at "X" under full line pressure,

STEAM FLOW CAPACITIES OF ORIFICE PLATES

ORIFICE	AREA	1.9 A K	STEAM PRESSURE POUNDS 30	40	50	60	70	80	90	100
		W	FLOW IS POUNDS OF STEAM PER MINUTE							
1/8"	.01227	.0146	.2064	.2980	.3686	.4144	.4730	.5316	.5901	.6485
1/4"	.04909	.0867	.8300	1.1931	1.4206	1.6564	1.9018	2.1372	2.3726	2.6074
3/8"	.11045	.1322	1.8693	2.6899	3.2217	3.7321	4.2832	4.8124	5.3436	5.8728
1/2"	.19635	.2350	3.3229	4.7791	5.726	6.671	7.614	8.556	9.498	10.438
5/8"	.30680	.3672	5.192	7.468	8.940	10.424	11.897	13.369	14.842	16.311
3/4"	.44179	.5287	7.409	10.753	12.884	15.009	17.129	19.249	21.370	23.484
7/8"	.60132	.7197	10.176	14.638	17.539	20.432	23.318	26.204	29.234	31.969
1"	.7854	.9401	13.293	19.121	22.910	26.689	30.449	34.229	37.998	41.779
1 1/8"	.9940	1.1898	16.823	24.200	28.998	33.778	38.549	43.320	48.091	52.860
1 1/4"	1.2272	1.4689	20.688	29.674	36.583	41.618	47.268	53.118	58.968	64.804
1 3/8"	1.4849	1.7782	25.145	36.166	43.354	50.452	57.513	64.744	71.874	78.987
1 1/2"	1.7671	2.1152	29.908	43.023	51.547	60.020	68.223	77.014	85.496	93.967
1 5/8"	2.0879	2.4884	35.101	50.492	60.496	70.478	80.429	90.384	100.338	110.268
1 3/4"	2.4068	2.8891	40.851	58.754	70.407	79.105	93.606	106.198	116.977	128.533
1 7/8"	2.7612	3.3051	46.724	67.226	80.548	93.851	107.088	120.559	132.692	146.812
2"	3.1465	3.7604	53.172	76.486	91.640	106.787	121.836	136.916	151.996	167.036

DERIVATION 1.9 A K $\sqrt{(P-d)d}$

passes through the pipes, orifice plates and out to the burner line at "Y" under a reduced pressure caused by the orifice plate obstruction in the flanges. Now suppose that as the steam flowed through the manifold the gages showed no drop in pressure as the steam passed through. It is evident then that the obstruction in the line is not sufficiently small to cause a reduction in pressure. Therefore we close one of the master valves and the lower pressure gage shows a drop of 5 lb. Assuming that the higher pressure is 90 lb. the lower gage would show 85 lb. Then assume that we closed the ½-in. plate; we know that the 1-in., ¾-in. and ⅝-in. plates are causing the 5 lb. drop. Upon these assumptions we may assume a problem to illustrate the calculation of steam flow from such data.

For this calculation, the formula is expressed as follows:

$$W = 1.9 \text{ A K } \sqrt{(P - d)d}$$

In which:

W = weight in pounds of steam per minute.
1.9 = constant
A = area of the orifice or sums of the areas of the orifices in square inches.
K = constant, for this plate 0.63
P = Absolute initial pressure
d = difference in the two pressures

Therefore:

90 lb. inlet pressure
90 + 14.7 = 104.7 absolute initial pressure
90 — 85 = 5=d

The orifice plates used were 1-in., ¾-in. and ⅝-in. and the 1.9 A K is derived as follows:

Area of 1-in. orifice 0.7854. Then 1.9 × 0.7854 × 0.63 = ... 0.9401
Area of ¾-in. orifice 0.4417. Then 1.9 × 0.4417 × 0.63 = ... 0.5287
Area of ⅝-in. orifice 0.3068. Then 1.9 × 0.3068 × 0.63 = ... 0.3672

Therefore A is the sums of all the orifice and is.... 1.8360

Solving:

$W = 1.8360 \sqrt{(104.7 - 5)5}$
W = 40.97 lb. of steam per minute
40.97 × 60 = pounds of steam per hour, or 2458.2 lb.
2458.2 ÷ 34.5 = b.hp. per hr. or 71.25 b.hp.

Then having determined the water rate of the burner line, from the fuel meter, or other suitable means of determining the fuel consumption, calculations can be made concerning the pounds of fuel fired per minute. From these two known quantities can be determined the pounds of steam per pound of fuel.

As shown in Fig. 5, if after the water rate of the burner line has been determined and it is desired to keep this data as a permanent record this installation will serve the purpose well. Where you have a steam consumption that will fluctuate either side of the dead line, one orifice can be made to do the work of the three just used. These three orifices are used to determine the size of plate needed in the one flange manifold. To determine the correct plate for this one flange consult the table shown in the following manner. By experiment we have found that 40.97 lb. of steam flows through the burner line per minute and that there is situated in the line 3 plates of 1-in., ¾-in. and ⅝-in. diameter respectively. The sums of the areas of these plates is 0.7854 + 0.4417 + 0.3068 a total of 1.5339 sq. in. One plate of this area will give us the same drop as three plates whose total area is that sum. The diameter of a circle having that area is 1⅜ in., approximately. The difference is slight. From the table it will be seen that an orifice of 1⅜-in. diameter has a capacity of 10.67 lb. per min. with a 1-lb. drop while with a 21-lb. drop the capacity is 78.98 lb. of steam per min., sufficiently adequate for the work to be done.

This kind of a permanent manifold enables the operator to collect data for computing burner efficiency at any time. By the installation of a double pen recording gage continuous records can be made of the burner steam consumption. Charts can be made showing the fireman when he is using too much steam. There is no limit to the valuable information to be gained from an installation of this kind.

In good practice, a burner should not consume more than 0.2 of a pound of steam per pound of fuel on normal operation and the entire system should not consume more than 5 per cent of the total steam developed. When you can honestly arrive at these figures your oil burning system is operating efficiently.

THE PULL-OUT torque of an induction motor is the maximum torque that it will develop at normal volts after being allowed to run up to normal speed, that is, the maximum torque the motor will develop when loaded to a point where it stalls. The pull-out torque is from 2 to 3.5 times the full-load torque depending upon the design of the motor.

Fineness Determination of Powdered Coal

HAND SIEVING IS RECOMMENDED AS A STANDARD METHOD, WHILE A RAPID METHOD, BY MACHINE SIEVING, IS SUGGESTED FOR ROUTINE TESTS. BY W. A. SELVIG AND W. L. PARKER

POWDERED or pulverized coal is extensively used as a fuel, the total annual consumption in the United States being about 12,000,000 T. As the coal is usually pulverized so that 70 per cent or more passes through a 200-mesh sieve, it presents difficulties in sieving, because such finely divided material tends to clog the meshes. A fineness test is desirable in order to judge the efficiency of the pulverizing apparatus, and as an indication of the particle size of the coal being burned.

Committee D-5 on Coal and Coke, American Society for Testing Materials, has recognized the desirability of a standard method for determination of fineness of powdered coal. The Bureau of Mines, in co-operation with this committee, conducted sieving tests on two standard samples of powdered coal, which are described in a recently published report. As a result of this work a method for making fineness tests, by hand sieving, is recommended as a standard method, while a rapid method, by machine sieving, is given for routine tests.

Requirements of the "United States Standard Sieve Series" which have been pretty generally adopted for laboratory sieves were specified for the testing sieves. The sieves used were the No. 100, 140, and 200. These correspond to the better class of testing sieves on the market, which are usually known as 100, 150, and 200-mesh sieves. The frames are circular, being about 20 cm. (7.87 in.) in diameter, with about 5 cm. (1.97 in.) between the top of the frame and the wire cloth. The wire cloth is made from brass, bronze, or other suitable wire, and mounted on the frames without distortion. The joint between the cloth and the frame is smoothly filled with solder, or so made that the material will not catch. The screens are not designated by mesh, but by abstract numbers, with specified size of opening, wire diameter, and tolerances in average opening, wire diameter, and maximum opening.

RECOMMENDED METHOD BY HAND SIEVING

Samples shall be air-dried in a drying oven at 10 to 15 deg. C. above room temperature. The drying shall be continued until the loss in weight is not more than 0.1 per cent per hour. A 50-gram sample of the air-dried coal shall be placed on the No. 200 sieve, to which a pan and cover shall be attached. The sieve shall be held in one hand in a slightly inclined position, so the sample will be well distributed, at the same time gently striking the side about 150 times per min. against the palm of the other hand on the up stroke. Every 25 strokes the sieve shall be turned about one-sixth of a revolution in the same direction. The sieve shall be held over a sheet of white paper while sieving, so as to detect any loss from accidental spilling, in which event another sample shall be taken.

After sieving for 1 min., the sieve pan shall be removed, and the material which has passed through the sieve discarded. The side of the sieve shall be tapped with a brush handle, and the coal adhering to the underside of the wire cloth brushed off. In tapping and brushing, the sieve cover shall remain on the sieve so as to prevent any loss of material over the side of the sieve. A 1 in. bristle brush is satisfactory for brushing the underside of the wire cloth.

Replace the sieve pan and continue sieving for 2 min.; then the tapping and brushing shall be repeated, and again repeated after 2 min. of additional sieving. Sieving shall then be continued in the usual manner, omitting the operations of tapping and brushing, until the amount passing through in 1 min. of continuous sieving is about 0.1 gram. Before weighing the material passing through the sieve, the side of the sieve shall be tapped with the brush handle in order to remove any material adhering to the underside of the wire cloth. The cover of the sieve shall then be removed, and the residue remaining on the sieve carefully removed. The sieve shall be inverted over a piece of white paper, and the wire cloth cleaned by carefully brushing the underside. The material removed from the wire cloth shall be added to the residue removed from the sieve.

After cleaning the sieve, the residue shall be placed thereupon, the sieve pan and cover attached, and the sieving resumed in the usual manner, omitting the operations of tapping and brushing, until not more than 0.05 gram passes through in 1 min. of continuous sieving, when the sieving shall be considered to be finished. The sieve shall then be inverted and cleaned as before, and the residue weighed.

Residue shall then be successively sieved on the No. 140 and 100 sieves. Sieving shall be continued in the usual manner, omitting the operations of tapping and brushing, until not more than 0.05 gram passes through in 1 min. of continuous sieving, when the sieving shall be considered finished. The sieve shall then be inverted, cleaned, and the residue weighed as described for the No. 200 sieve. As the fine material that tends to cause clogging has been removed by sieving through the No. 200 sieve, it is not necessary to brush the underside of the wire cloth or clean the sieves during the sieving operation, as was done for the No. 200 sieve.

Fineness shall be calculated from the weights of the residues on the sieves, and shall be expressed as percentages of the weight of the original sample. The fineness shall be reported as follows:

FINENESS TEST

Sieve Number	Per Cent
On 100.....	
On 140, through 100.....	
On 200, through 140.....	
Through 200.....	

In duplicate tests with the same sieves, the same operator, should check within 1 per cent on all sizes. Different operators using different sieves should check within 3 per cent on the through 200 material.

ROUTINE METHOD BY MACHINE SIEVING

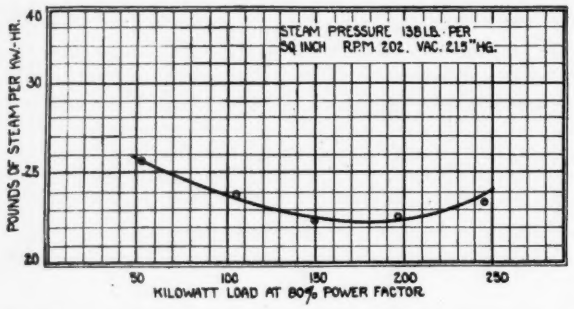
For routine testing, mechanical sieving devices by which a number of sieves are shaken at the same time afford a convenient method of making the fineness test. The hand-sieving method should be considered the standard, and the results obtained by machine sieving should be compared to those obtained by hand sieving to see whether the sieving action of the machine is practically the same as by hand sieving.

The same sieves should be used as specified for hand sieving, and these sieves should be provided with tight-fitting pans and covers to prevent possible loss during sieving. Fifty grams of air-dried coal is placed on each sieve, and the sieves are shaken until not more than about 0.1 gram passes through the No. 200 sieve in 1 min. of continuous sieving. The sieves are then inverted and brushed clean, as described for the No. 200 sieve in the method for hand sieving. Sieving is then resumed until not more than 0.05 gram passes through the No. 200 sieve in 1 min. of continuous sieving, when the test shall be considered finished, after which the sieves are inverted and cleaned as before and the residues remaining on the sieves weighed. The fineness is calculated and reported as in the hand-sieving method.

Advantages of Uniflow Steam Engines

HIGH EFFICIENCY AND LONG LIFE MAKE THIS TYPE ENGINE POPULAR. BY C. A. JOERGER

THAT interesting type of steam engine—the uniflow engine, is becoming extremely popular in this country. A presentation of the reasons for its popularity seems worth while. The thermal conditions existing in a steam engine



WATER RATE OF A UNIFLOW ENGINE GENERATING UNIT

having a "hot" inlet at the ends of the cylinder and a "cold" exhaust at the center were understood and stated by J. L. Todd, of England, in the year 1885. He should be credited with the invention of the uniflow engine although some of his experiments were along incorrect lines. For several years, nothing of much consequence was done with the uniflow idea until Professor J. Stumpf of Charlottenburg, Munich, Germany, began to experiment with and design engines of this type. The present extensive use of uniflow engines with their improved economies and designs is almost wholly due to Professor Stumpf. It is only recently that this type of engine has become popular in this country as the prime mover for medium-sized power plants. Now the majority of engine builders are adding to their line of products an engine which has central exhaust ports.

Professor Stumpf went about to do in one cylinder what was usually done in two or three; that is, to obtain an economy with a single expansion such as was possible in a compound or triple expansion. He resolved to do this after the manner of the steam turbine, with steam flowing in one direction only, and applied Todd's principle of hot admission and cold exhaust. This led to the adoption of an early cutoff, thus obtaining large ratios of expansion, and also to higher compression, which permits high speeds and small clearances.

The main advantage of the uniflow engine is that initial condensation is largely eliminated and consequently less re-evaporation takes place later in the stroke. This advantage is brought about by passing the exhaust steam out through large ports in the center of the cylinder. The cylinder heads being either steam jacketed or insulated, the steam near the ends remains hot and dry and the wettest steam follows the piston and drops out of the exhaust ports. Therefore, the piston is the only metal which is cooler than the incoming steam and much initial condensation is eliminated. The heat of the high compression heats the clearance steam to a temperature nearly equal to that of the initial conditions. The large central exhaust ports permit the lower pressure in the cylinder to reach more nearly the pressure of the condenser. There is little chance for exhaust valve leakage, since the packing rings of the long piston insure absolute tightness.

All tests of uniflow engines have shown the steam consumption curve to be quite flat over a large load range. This is an important advantage especially in the case of small factories where one unit carries the entire load which is usually unsteady and varying. The uniflow engine has a large over-load capacity due to its normally early cutoff which can be increased with only slight decrease of economy. The mechanical efficiency of a uniflow is slightly higher on account of its simplified valve gear and it has only one cylinder instead of two, as on a compound engine of equal capacity.

Uniflow engines are generally equipped with poppet valves and have, therefore, the advantages of the poppet valve which are:

1. No rubbing surfaces; hence no lubrication and, therefore, adaptable to higher temperatures.
2. Small weight and practical balance; hence its adaptability for high speed and high steam pressure.
3. No appreciable wear; hence engine economy maintained for an indefinite period.

To show clearly the difference in weight, a certain Corliss valve weighs 206 lb. for a free area of 65 sq. in. and a poppet valve for the same free area weighs 18 lb. The power to operate the valve is therefore much less with poppet valves, particularly at high speeds, due to the inertia of the heavy valves and rocker arms of the Corliss gear. The high pressures employed increase friction between a sliding valve and its seat, while there is no friction at all between a poppet valve and its seat; therefore a poppet valve should retain its seat indefinitely when once properly ground in.

In the chart are given the results of an economy test recently conducted by the author on a 21 by 22-in uniflow engine, generator 325 kv.a., 80 per cent power factor; dry saturated steam was used. There is clearly an excellent economy over a wide range.

A BRASS POLISHING paste that gives good results may be made up as follows: camphor gum, 1 oz.; alcohol, 2 oz.; spirits of ammonia, 2 oz.; spirits of turpentine, 4 oz.; candle paraffine, 1 lb.; clean tallow, 1 lb.; tripoli, 1 lb. For compounding, first dissolve the camphor in the alcohol, then melt down the tallow and paraffin and stir in the liquids and the tripoli. Before cooling, the paste can be packed in boxes of convenient sizes for use.

Computing the Economies of Labor-Saving Equipment

Important Items Are Often Omitted in Comparative Costs

COAL and ash handling in the boiler plant are problems similar in practically all respects to those of material handling in a factory. They constitute a problem of economics which must be solved to determine whether it will be profitable to install mechanical equipment and if so just how much of an expenditure is justified when compared to the saving effected.

Recently the Materials Handling Division of the A. S. M. E. have presented formulas for computing the economics of labor-saving equipment. These are applicable to the problems of ash and coal handling in the boiler plant. The entire problem is considered as one of comparative costs.

In computing the costs, frequently the labor to be saved has been classed as indirect or non-productive labor and as such is a part of the overhead or burden and should, therefore, not bear any superimposed charge from the other components of the overhead. This would be pyramiding the charges but where comparative costs of the economics are desired, then the indirect or non-productive labor should be charged with all the other component parts of the overhead with the exception of itself. In other words, the difference in labor as obtained by subtracting the labor used in the new saving method or device from the old method or device must be loaded with its proper share of the burden or overhead applied to both productive and non-productive labor in correct relative proportion.

Two common mistakes then have been made, rendering it difficult to secure proper comparative results and frequently obscuring the issue:

(1) The omission of burden or overhead charges on that portion of labor saved in comparing costs.

(2) The omission of burden charges on indirect labor in comparing costs, although they were added to the direct labor.

The following rule, therefore, for setting a value upon labor saved by an improved process has been evolved: Whatever valuation is arrived at, in cost accounting, as the cost per unit of labor used in production, also establishes the value per unit of labor saved by an improved process. For simplicity, no monetary value need be placed upon labor employed in comparative processes, except upon the amount of difference in labor required at the current rate plus "burden" or an equivalent.

With the above consideration as a foundation, the formulas for calculating economics of labor-saving equipment are set forth herewith.

Let the debit items be:

A = percentage allowance on investment
B = percentage allowance to provide for insurance, taxes, etc.
C = percentage allowance to provide for upkeep
D = percentage allowance to provide for depreciation and obsolescence
E = yearly cost of power, supplies, and other items which are consumed, total in dollars

and the credit items be:

S = yearly saving in direct cost of labor in dollars
T = yearly saving in fixed charges, operating charges or burden, in dollars
U = yearly saving or earning through increased production, in dollars
X = percentage of year during which equipment will be employed
I = initial cost of mechanical equipment

Results will be:

Z = maximum investment in dollars justified by the above consideration
Y = yearly cost to maintain mechanical equipment ready for operation
V = yearly profit from operation of mechanical equipment

$$Z = \frac{(S + T + U - E)\ X}{A + B + C + D} \quad \ldots\ldots (1)$$

$$Y = I(A + B + C + D) \quad \ldots\ldots (2)$$

and

$$V = [(S + T + U - E)X] - Y \quad \ldots\ldots (3)$$

Feeling that handling machinery, even if left idle a large part of the year, would probably require, under most conditions, approximately the same repair through deterioration as though in use, the Committee makes no deduction for such lack of use in the estimated cost of upkeep C. If greater accuracy be considered necessary, use C multiplied by X in place of C in the formulas.

The credit item U should not be considered when applying these formulas to power plant problems for the reason that the application of mechanical handling equipment will not result in increased earnings due to increased production. This item is important, however, in the consideration of factory problems.

As an example of the application of these formulas we may assume that the coal handling for a boiler house has formerly been done by four men receiving $4 a day each, or, allowing 300 days per year, at an annual direct cost of $4800, can be done by one man operating a system of conveyors at a direct-labor cost of $1200 a year, thus effecting a saving at the rate of $3600 a year in direct-labor cost.

We may further assume that the labor involved, being accounted as "non-productive," carries a fixed charge or burden of 10 per cent. In actual practice, the plant operates 240 da. per yr. or 80 per cent of the time. The various factors, therefore, are estimated as follows:

A = 6 per cent	E = $ 500
B = 4 per cent	S = $3600
C = 10 per cent	T = 360
D = 15 per cent	X = 80 per cent

$$Z = \frac{(3600 + 360 - 500) \times 80}{6 + 4 + 10 + 15} = \$7909$$

This indicates that equipment costing any sum below $7909 will earn some profit above interest on investment and maintenance.

Assume that the conveying system costs $6000. Then the yearly cost to maintain the equipment ready for operation, exclusive of labor, will be expressed by the formula

$$Y = I\ (A + B + C + D)$$

or 6000×35 per cent equals $2100. Then the profit or gain from the operation of the mechanical equipment, according to formula (3), becomes

$$V = (3600 + 360 - 500) \times 0.80 - 2100 = \$668.$$

This represents an annual earning upon the initial investment, or over all items of cost, of over 11 per cent.

Setting the Valves of a Diesel Engine

By Following Through Separately Each Event, Valve Setting Becomes a Simple Process. By H. F. Birnie and R. C. Baumann

TO THE OPERATOR, valve setting, or timing, is often an obscure subject and the engine erector is not always ready to explain everything to him. In fact, some erectors or factory assembly foremen often go so far as to make a deep secret of the matter as if there were some mysterious trick to valve setting which should not be allowed to become common knowledge.

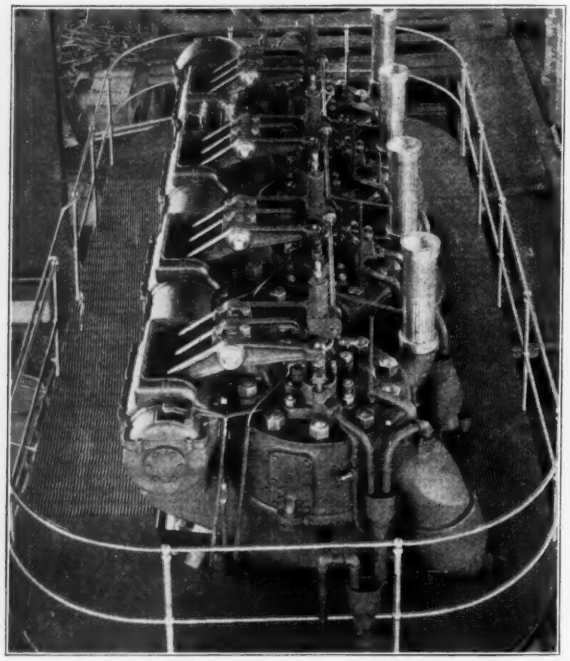


FIG. 1. LOOKING DOWN ON THE ROCKER ARMS WHICH OPERATE FUEL, INTAKE AND EXHAUST VALVES

In order to make the general process of valve setting easy to grasp let us go step by step through the routine of timing a typical engine, say for instance a three-cylinder, four-cycle air injection Diesel having the following characteristics: Firing order 1-2-3. Fuel, exhaust and intake valves actuated by rocker arms, the cams acting directly on the rocker rollers. The cam shaft to be driven by a vertical shaft and helical gears. Starting valves to be opened by compressed air which in turn is controlled by pilot valves operated from the main cam shaft. The fuel pump is to be driven by eccentrics on the cam shaft with an individual plunger for every working cylinder.

In the cylinder of a four-cycle Diesel engine, a power stroke occurs every two revolutions of the flywheel or every 720 deg. Thus for a three cylinder engine there will be a power stroke every $720 \div 3 = 240$ deg. If now we number the cranks of the crank shaft No. 1 at the flywheel end, No. 2 in the middle and No. 3 at the compressor end, firing order being 1-2-3-, the crank No. 2 must follow crank No. 1 by 240 deg. when we rotate the crankshaft in the direction of running. It will be noticed that if we reverse the direction of running the firing order instead of being 1-2-3 will be 1-3-2.

In the four-cycle engine, the four-piston strokes per cycle occur in the following sequence as shown by Fig. 2. (1) The power stroke during which fuel is injected during the early part of the stroke and the heated gases expand as the piston is driven toward the crank end. The fuel

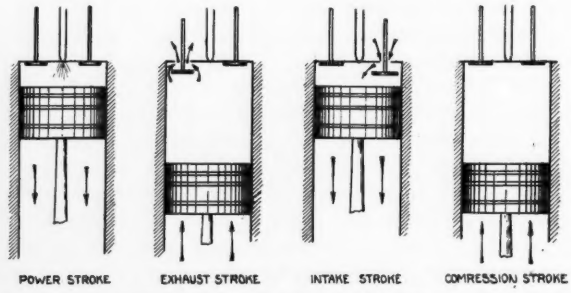


FIG. 2. ILLUSTRATING THE FOUR STROKES OF THE FOUR-CYCLE ENGINE

valve is open a short period, intake and exhaust valves are closed. (2) The exhaust stroke during which the piston is moved upward or away from the crank end and expels the burnt gases. The exhaust valve is open while fuel and intake valves are closed. (3) The intake stroke during which the piston is moved downward drawing in fresh air. The inlet valve is open and the fuel and exhaust valves are closed. (4) The compression stroke during which the piston again moves upward and all valves are closed.

All Valves Open Before Dead Center Positions

Due to the mechanical limitations of not being able to open valves to their full opening immediately and to restrictions offered to the passage of the gas through the valves, gas ports and manifolds, the best performance is not obtained unless the various valves are made to open somewhat in advance of the beginning of the stroke during which they are to be open. That is the valves start to open before the dead center positions, this advance is called the valve lead. The best lead for a given engine depends principally upon the cam contour and upon the engine speed. A typical setting for a medium engine speed (200-

LENGTH IN INCHES EQUIVALENT TO THE VALVE LEAD FOR DIFFERENT FLYWHEEL DIAMETERS

DIAMETER OF FLYWHEEL	7'-2½"	7'-9"	9'-0"	10'-0"	11'-0"	12'-0"
DISTANCE ON FLYWHEEL RIM EQUIVALENT TO 1°	3/4"	13/16"	15/16"	1 3/64"	1 5/32"	1 1/4"
" " 5°	3 49/64"	4 1/16"	4 45/64"	5 15/64"	5 49/64"	6 17/64"
" " 10°	7 9/16"	8 7/64"	9 13/32"	10 15/32"	11 33/64"	12 35/64"
" " 22°	16 39/64"	17 55/64"	20 45/64"	23 3/64"	25 23/64"	27 39/64"
" " 41°	30 61/64"	33 1/4"	38 39/64"	42 51/64"	47 15/64"	51 13/64"
" " 45°	33 61/64"	36 1/2"	42 19/64"	47 13/64"	51 5/64"	56 29/64"

250 r.p.m.) would be as follows: fuel valve opens 5 deg. before piston reaches top dead center on the compression stroke. Exhaust opens 41 deg. before the piston reaches bottom dead center on the power stroke. Intake opens 22 deg. before the piston reaches top dead center on the exhaust stroke.

Valve leads being given in degrees it will be necessary to convert them into inches of flywheel circumference so that they may be marked directly on the flywheel. If the circumference of the flywheel measured with a tape line is for instance 379 in., then 1 degree

$$= \frac{\text{circumference of flywheel}}{360} = \frac{379}{360} = 1.053 \text{ in.}$$

on the flywheel. The table given herewith gives the length in inches equivalent to the lead of the valves for different flywheel diameters.

In four-cycle engines the drive of the camshaft is arranged so as to turn it with just half the speed of the flywheel, in other words, while the flywheel makes two revolutions the camshaft only makes one. A complete revolution of the camshaft (360 deg.), thus represents 720 deg. on the flywheel. The four strokes of each of the three cylinders of the engine we have in mind have to be completed during these two revolutions of the flywheel and one revolution of the camshaft. All the exhaust, inlet and fuel valves must come into play during one revolution of the camshaft.

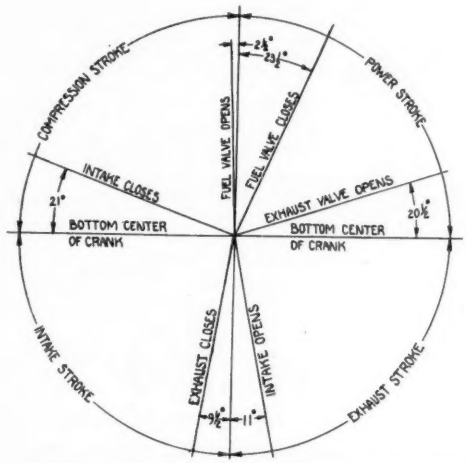


FIG. 3. VALVE EVENTS LAID OUT ON THE CAM SHAFT CIRCLE

Cam Shaft Rotates at Half the Crankshaft Speed

Let us consider the cams of cylinder No. 1 only, for the present and set their leads which were expressed in degrees of flywheel rotation. If we want to express them in degrees measured on the camshaft, it will be necessary to take half of their values. In other words, measured on the camshaft circle, the fuel valve opens 2½ deg. before top center, the exhaust valve opens 69½ deg. after top center and the intake valve opens 169 deg. after top center, as shown by Fig. 3.

Valve events for cylinder No. 2 follow those of cylinder No. 1 by 240 deg. of crankshaft rotation or 120 deg. of the camshaft circle. Thus, fuel valve No. 2 opens 120 deg. — 2½ deg. = 117½ deg. after top center No. 1. Exhaust valve No. 2 opens 120 deg. + 69½ deg. = 189½ deg. after top center No. 1 and intake valves No. 3 opens 120 deg. + 169 deg. = 289 deg. after top center No. 1.

Cylinder No. 3 follows No. 1 by 480 deg. on the crankshaft consequently its valve events measured on the camshaft will follow the corresponding events for cylinder No. 1 by 240 deg. on the camshaft. Thus fuel valve No. 3 opens 240 deg. — 2½ deg. = 237½ deg. after top center of No. 1, exhaust valve No. 3 opens 240 deg. + 69½ deg. = 309½ deg. after top center of No. 1 and intake valve No. 3 opens 240 deg. + 169 deg. = 409 deg. after top center of No. 1.

By following the increasing values of the opening angles on the camshaft the various valves will be found to open in the sequence as shown in the following tabulation:

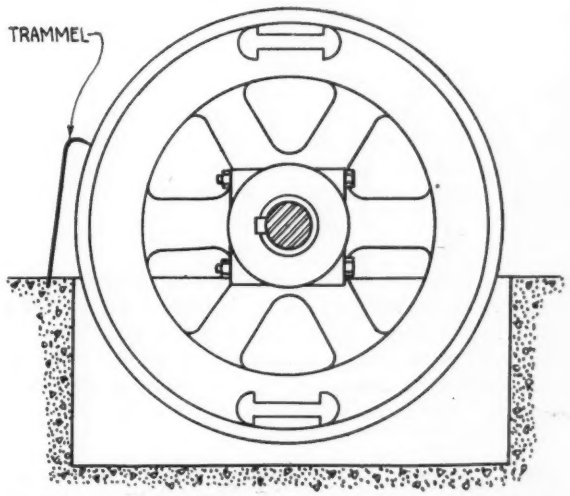


FIG. 4. TRAMMEL IS HANDY TO USE WHEN LOCATING DEAD CENTERS

Firing order:

1-3-2 3 Cylinders	1-2-3 3 Cylinders	1-2-4-3 4 Cylinders
Fuel 1	Fuel 1	Fuel 1
Exhaust 1	Exhaust 1	Exhaust 1
Fuel 3	Fuel 2	Fuel 2
Air Intake 1	Air Intake 1	Exhaust 2
Exhaust 3	Exhaust 2	Air Intake 1
Fuel 2	Fuel 3	Fuel 4
Air Intake 3	Air Intake 2	Exhaust 4
Exhaust 2	Exhaust 3	Air Intake 2
Air Intake 2	Air Intake 3	Fuel 3
		Exhaust 3
		Air Intake 4
		Air Intake 3

Actual work of setting the valves should begin by marking upon the flywheel the necessary datum points. The first of these to be determined are the top and bottom dead centers of each crank. Since in a four-stroke cycle engine there are two top centers and two bottom centers per cycle, care must be taken to avoid confusion in marking the flywheel. On the edge of the flywheel pit, a small reference punch mark is made which acts as a socket into which one end of a pointed trammel may rest. This trammel should be used as shown in Fig. 4, it may be of any convenient length.

Beginning with cylinder No. 1, the flywheel is barred over until the piston is near the upper end of its stroke.

A steel block, somewhat thicker than the clearance between the piston top and the cylinder head is now placed upon the flat part of the piston top as shown in Fig. 5. Access to the cylinder is gained by removing the intake valve cage. The barring over is now continued until the steel block jams lightly between the piston top and the cylinder head and prevents further rotation. A mark is then

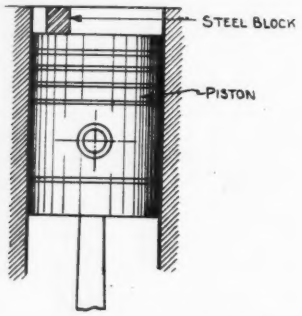


FIG. 5. METHOD OF LOCATING DEAD CENTER BY USE OF A STEEL BLOCK

scratched upon the flywheel rim with the sharp point at the upper end of the trammel as its lower end rests in the socket in the floor. After removing the steel block the engine is turned further in the same direction until the piston passes its maximum upward position and starts receding. The block is again placed on the piston top,

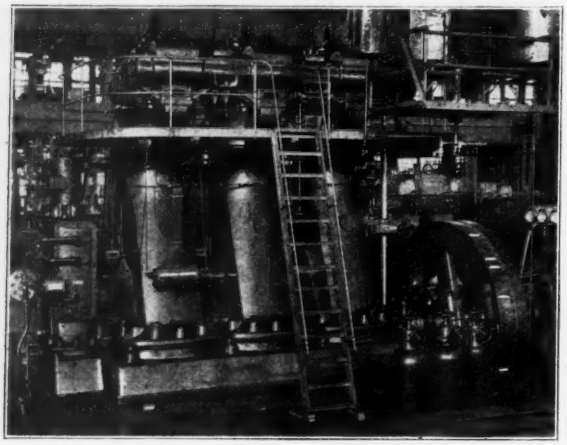


FIG. 6. ENGINE COMPLETELY ASSEMBLED SHOWING MARKS ON FLYWHEEL

care being taken that it is returned to the same position it occupied previously. The engine is now backed up until the block again touches the cylinder head and a second mark is made on the flywheel with the trammel.

Having determined, in this way, two points on the flywheel at equal distances from the top dead center of crank No. 1, the desired top dead center reference point is therefore midway between the two scratches. This mid-point should be permanently marked and designated No. 1 T. D. C. Having determined the top center we can lay off directly with a tape line the bottom dead center, which makes a convenient reference point from which to measure the exhaust lead.

Tape Line Used to Layoff Points on Flywheel

After the top center of No. 1, the next firing top center will be No. 2 after 240 deg. of rotation of the flywheel. This is most easily located by laying off two-thirds the circumference of the flywheel with a tape line from the top center mark of No. 1, or by repeating the operation stated above. The bottom and top dead center marks for each crank should be established before proceeding further.

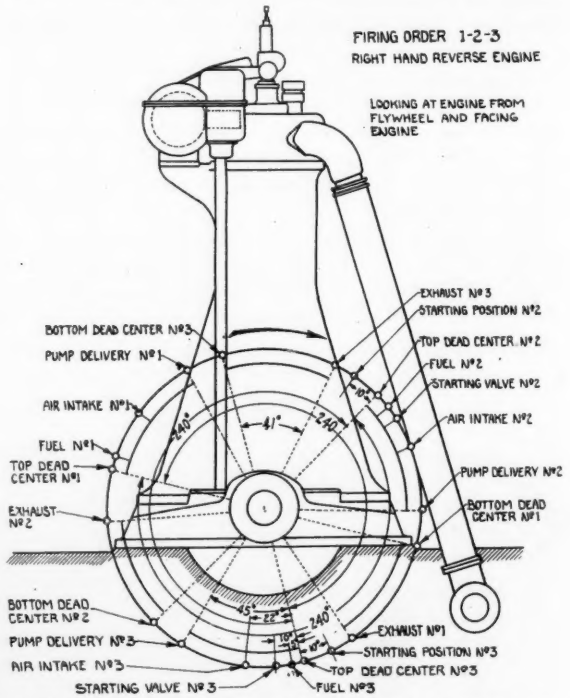


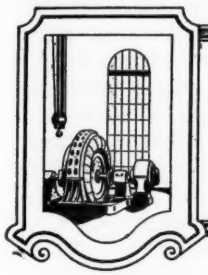
FIG. 7. DIAGRAM SHOWING MARKINGS ON FLYWHEEL OF A THREE-CYLINDER ENGINE

It is now possible to lay off the various valve leads on the flywheel and thus determine the points at which the respective valves should begin to open, keeping in mind the direction of engine rotation. The points of valve opening thus established should be marked and labeled properly.

The second operation which must precede the actual setting of the cams is the adjustment of the clearances between the rocker arm rollers and the cams on the camshaft. These clearances are necessary to insure a firm seating of the valve. For engines of medium size with camshafts at the level of the cylinder heads the following clearances may be used for fuel cam measured between cam base circle and roller 0.008 in., for inlet cam measured between cam base circle and roller 0.010 in. and for the exhaust cam measured between cam base circle and roller 0.012. A feeler gage should be used for this work and all setting done when the engine is cold.

When the camshaft is some distance below the cylinder heads and push rods are interposed between the cam rollers and the rocker arms the clearances may increase as the engine warms up. This is caused by the expansion of the cylinder causing the rocker arm to be lifted off the push rod. This expansion of the cylinder is great enough to counteract entirely the small expansion of the valve stem.

Work incidental to the timing of Diesel engine valve gear with practical information relative to its operation will be included in the second installment of this series.



ELECTRICAL MACHINERY FOR LIGHT AND POWER

Operation of A. C. Generating Apparatus---II

FURTHER CONSIDERATIONS REGARDING PHASE RELATIONS OF VOLTAGE AND CURRENT IN A. C. CIRCUITS. BY V. E. JOHNSON

TO ILLUSTRATE fully the method by which two voltages are added in alternating-current circuits, let us assume the practical case shown in Fig. 1. Here we have two alternators in series, having voltmeters connected as shown. When the machines are in step, that is, when the voltages are in phase, it is apparent that the voltmeter C would indicate the arithmetical sum of the readings on a and b, in this case 200 v.

If the phase relations were such that there was a displacement of 90 deg. between the voltages, the voltage c would be 141 v. If the phase displacement was 180 deg., then the voltmeter c would read zero.

These values are most easily obtained graphically, drawing the voltages to scale and making the angles between the lines be the angular displacement of the voltages. Figure 2 illustrates this graphic method for the three conditions described. Here the vector lengths are chosen to represent measured effective values. A shows the two voltages in phase, B shows them displaced by 90 deg. and C shows them out of phase or in opposition.

In Fig. 3 are shown the actual sine waves corresponding to the voltages indicated in Fig. 2. The curves ab and bc actually lie on top of each other but are shown slightly displaced for the sake of clearness. The resultant wave ac is the sum at any moment of the values of the curves ab and bc. The lines e-e and E-E represent the effective values of the component and the resultant waves respectively. E-E is equal to 2(e-e).

The actual sine waves corresponding to B in Fig. 2 are shown in Fig. 4. The curves ab and ad are displaced by 90 deg.

Adding the various instantaneous values a resultant curve ac is obtained having a maximum value M and an effective value E-E. This effective value E-E is less than the arithmetical sum of ee + ee, the effective values of the component. It will be seen, too, that ac is 45 deg. ahead of ad and 45 deg. behind ab which corresponds to the results obtained by the vector addition.

Figure 5 shows the actual sine waves corresponding to C in Fig. 13. The resultant is the zero line E-E. This again checks with the result of the vector addition. The

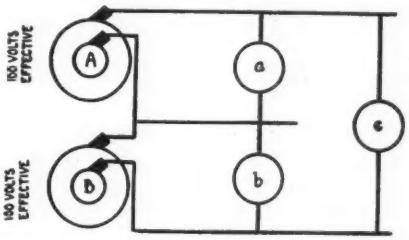


FIG. 1

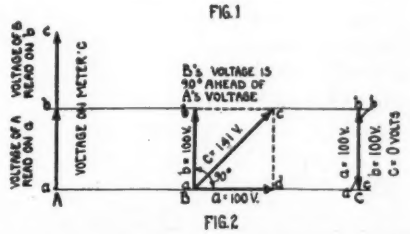

VOLTAGE OF B READ ON b
VOLTAGE ON METER C
VOLTAGE OF A READ ON a
B's VOLTAGE IS 90° AHEAD OF A's VOLTAGE
b = 100 V.
C = 141 V.
45°
a = 100 V.
a = 100 V.
b = 100 V.
C = 0 VOLTS

FIG. 2

FIG. 1. TWO ALTERNATORS CONNECTED IN SERIES
FIG. 2. GHAPHIC METHOD OF ADDING VECTORS

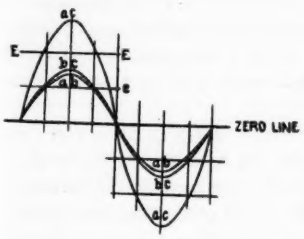


FIG. 3

FIG. 3. SINE WAVES CORRESPONDING TO VECTORS OF FIG. 2

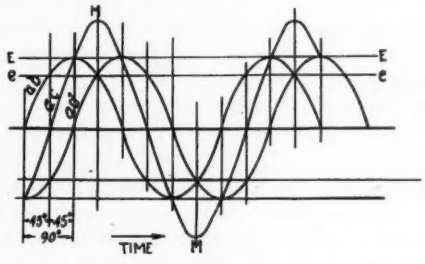


FIG. 4

FIG. 4. SHOWING ADDITION OF TWO VOLTAGES 90 DEG. APART

The values e and E are effective values in B, Fig. 2, but drawn to a smaller scale.

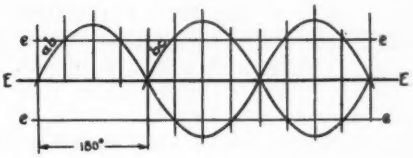


FIG. 5

FIG. 5. TWO VOLTAGE WAVES 180 DEG. DISPLACED

The distance corresponding to the value e is that represented by the vectors ab or bc in C, Fig. 2, but drawn to a different scale. In this case E-E the resultant coincides with the zero line.

effective value ee of the curve ab is equal and opposite to the effective value ee of the curve be and the sum is therefore zero.

Three voltages would be added in the same way. For example, assume three alternators connected as in Fig. 6, and having a displacement of 45 deg. The vectors would be represented by the lines drawn as in Fig. 7. Here the sum is ad as shown. In angular position, it will be seen

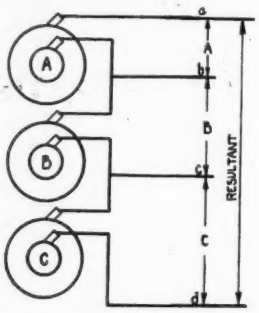
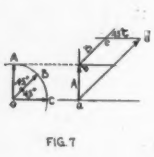


FIG. 6. THREE A. C. GENERATORS CONNECTED IN SERIES

that ad is 45 deg. ahead of cd, in phase with be, and 45 deg. behind ab.

Figure 8 shows the three component sine curves, and their resultant. The maximum values of these curves are equal to 1/.707 times the effective values as drawn in Fig. 7, while the latter are those designated by the line e-e for the component voltages, and the line E-E for the resultant.

So far the vectorial solutions have dealt with voltages only. The same methods would apply to the addition of currents, whether in phase or displaced by any number of degrees. In fact, by substituting the word "current" for



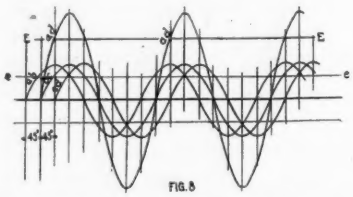


FIG. 7. VECTORS OF THREE VOLTAGES EACH DISPLACED 45 DEG. FROW THE OTHER

FIG. 8. DIAGRAM SHOWING ADDITION OF THREE VOLTAGE WAVES EACH DISPLACED 45 DEG. FROM THE OTHER

the word "voltage" the entire preceding discussion can be applied to the solution of currents.

Effect of Capacity in A. C. Circuits

Thus far we have considered currents and voltages and the addition of either of these at various phase displacements. Now if an alternating voltage of F cycles per second be impressed upon a closed circuit such as a lamp, motor or flat iron, a current will flow, and this will obviously have as many alternations per second as the impressed voltage; i. e., its frequency will be F cycles per second.

It is also to be noted that alternating current will flow through a condenser—such as a telephone condenser or a Leyden jar—even though the circuit be in the ordinary sense of the word, open. This current is really that due to the charging and discharging of the plates. A transmission line, open-circuited at the distant end, is in effect a two-plate condenser in which the wires are the plates. There is also a condenser effect between the wires as one plate, and the earth as the other. In actual practice, it is found that long high voltage lines take heavy charging currents and that it is possible to place full ampere load upon a generator with no metallic connection between its terminals.

Although the current which flows through a circuit is of the same frequency as the voltage which causes it to flow, it does not follow that the current and voltage are in phase.

Some electrical loads have a characteristic commonly (though incorrectly) termed "electrical inertia," which delays the current waves, and causes them to come to a maximum some part of a cycle behind the maximum point on the impressed voltage wave. In this case the current is said to lag behind the voltage, and the amount of this lag is measured in electrical degrees. In other words, there may exist a phase displacement between the voltage im-

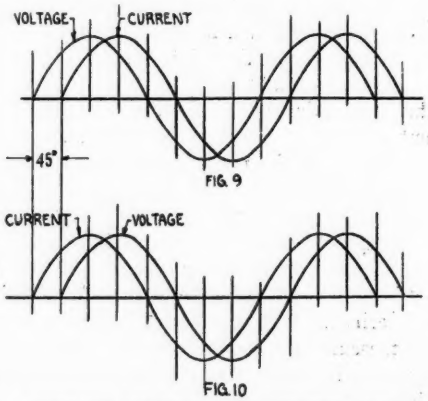


FIG. 9. VOLTAGE LEADING THE CURRENT BY 45 DEG.

FIG. 10. CURRENT LEADING THE VOLTAGE BY 45 DEG.

pressed on a circuit, and the current flowing in it, just as there may be phase displacement between two different voltages, or two different currents.

Stranger still, the current in a circuit sometimes actually comes to a maximum before the impressed voltage which causes it to flow. In this case, the current is said to lead the voltage, the displacement being as before, measured in degrees.

In Fig. 9 is shown a voltage wave, and a current wave lagging 45 deg. while in Fig. 10 the current leads 45 deg.

In a direct-current circuit, the amount of power generated or consumed is equal to the product of the impressed voltage and the current flowing. Power being expressed in watts—we obtain this formula:

$$\text{Volts} \times \text{amps.} = \text{watts.}$$

The same rule applies to the instantaneous power in an alternating current circuit. That is to say, at any given instant volts $\times$ amps. $=$ watts. However, it is evident that the average power delivered to the circuit can *not* be obtained by multipying effective volts by effective amperes, as we have not then taken into consideration the phase relation between the current and the voltage in the circuit.

In Fig. 11 is a circuit having zero phase displacement. The curve V is the voltage, C the current and P the power. At every instant the power is the product of the current and voltage.

Note that the voltage and current have negative values simultaneously, but that this, too, makes a positive power curve. This is like reversing both field and armature of a direct-current motor, which does *not* reverse the direction of rotation. In this case the average power is equivalent to the value e-e and a wattmeter would indicate this amount.

Figure 12 shows a circuit in which the current and voltage are displaced by 90 deg. and it will be seen that although the effective values of both are the same as in Fig. 11 and would read the same on the measuring instruments, yet the power curve has equal positive and negative loops so that the average value is zero; in other words, the amount of power delivered to the circuit at one instant, is returned by it to the generator at another. The wattmeter would indicate zero, yet the machine and load would, so to speak, be tossing blocks of power back and forth between them, as two boys toss a baseball. In the latter

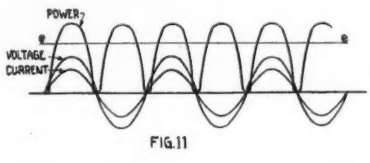


FIG. 11

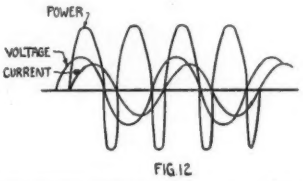


FIG. 12

FIG. 11. CURRENT AND VOLTAGE WAVES WITH ZERO DEG. DISPLACEMENT TOGETHER WITH POWER WAVE

FIG. 12. CURVES SHOWING CURRENT AND VOLTAGE DISPLACEMENT

case, the boys would be as fatigued as if they had been passing the ball in the same direction and so actually transporting it somewhere. In the former case, the generator and load would have carried as much current and would have been heated as much (actually more, as will be seen later) as if they had really been developing useful power.

Power Factor

In order, therefore, to find the power developed in an a. c. circuit, it is necessary to know how much the current and voltage are displaced. In Fig. 13 are shown graphically an effective voltage e and the effective current I produced by it in a circuit. They are displaced by the angle ϕ. In order to find the power in this circuit, it is necessary to find what portion of the current is in phase with the voltage—or as it is usually expressed, we must derive the power component of the current. This is done by projecting it to the voltage axis as shown. Thus OA is the power component, and the power equals OA $\times$ Oe. By trigonometry we know that OA = OI $\times$ cos. angle ϕ. (This cosine value can be obtained from tables found in almost every handbook.) Hence the power equals W = Oe $\times$ OI $\times$ cosine ϕ.

Figure 14 shows the sine curves corresponding to the vectors in Fig. 13. As these vectors represented effective values, they had to be multiplied by 1/.707 in order to give the maximum value.

The power loops above the zero line represent energy delivered by the generator to the line, while the negative loops represent the energy returned by the line to the generator. The total net energy is, of course, represented by the algebraic sum of the areas of the power loops, and the average power equals this algebraic sum divided by the length of the cycle.

It must be remembered that in this case, (as in all others) the angular relation between voltages and currents, as expressed above, has no geometrical significance, being merely measures of displacement using 1/360 of a cycle or one degree as a unit.

We have seen then that Watts = e $\times$ I $\times$ cos. ϕ.

Therefore Kilowatts $= \dfrac{e \times I \times \cos.\ \phi}{1000}$ where e and I are effective values as metered, and kilowatts is the average value as measured by a voltmeter.

In dealing with A. C., it is customary to designate the product of volts and amperes as volt-amperes—or kilovolt-amperes, $\dfrac{(\text{volt amperes})}{1000}$ and the symbol for this is kv.a. Therefore from the above formula it is seen that kv.a $\times$ cos. ϕ = kw. Hence cos. ϕ is the factor which mul-

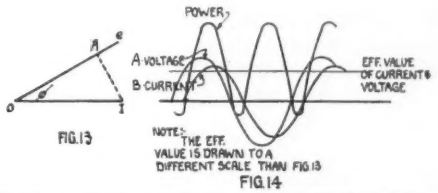


FIG. 13 FIG. 14

FIG. 13. GRAPHIC REPRESENTATION OF AN EFFECTIVE CURRENT I AND AN EFFECTIVE VOLTAGE E

FIG. 14. SINE CURVES CORRESPONDING TO VECTORS IN FIG. 13

tiplied by the kv.a. or apparent power, gives the kw. or actual power. From this cos. ϕ gets the name which is so commonly used, namely "power factor."

In Fig. 11, the current and voltage are in phase, therefore the angle of displacement is zero. The cosine of the angle zero is 1, hence the power equals eff. volts $\times$ eff. amps. $\times$ I = watts. In this case the power factor is "one"—or as it is more commonly stated, "unity."

In Fig. 12, the current and voltage are displaced say, 90 deg. The cosine of 90 deg. is zero hence, the power factor (P.F.) is zero.

$$\text{Kw.} = \frac{I \times e \times 0}{1000} = 0.$$

Every phase displacement has a power factor corresponding to it—which may be obtained from a table of cosines.

The Wattless Component

As previously stated, the power component of the current is equal to the actual current as measured, multiplied by the cosine of ϕ. This separation of the current into a power component and a wattless component (the wattless component equals I $\times$ sin ϕ) is shown geometrically in Fig. 15, where the current is the hypothenuse of a right angled triangle, the altitude is the wattless component, and the base the power component. The separation of the current is, of course, wholly imaginary, as far as physical action is concerned, being really only a mathematical convenience. However, the terms are very commonly used, and we find that "wattless current" occupies a prominent place in discussions covering electrical machinery.

Referring now to Fig. 11, it is seen that the current is all in phase with the voltage, and there is no wattless current.

In Fig. 12, the current is all wattless and there is no power component, yet the circuits in these two figures may be in series with each other so that the same current passes through each. The point to be borne in mind is that current is current, and voltage is voltage, and that the terms wattless component and power component are applied to give a better conception of the power relations in a circuit. This is made a little clearer by using a mechanical analogy. A horse pulling a load uphill uses part of his strength in raising the load against the downward pull of gravity, and

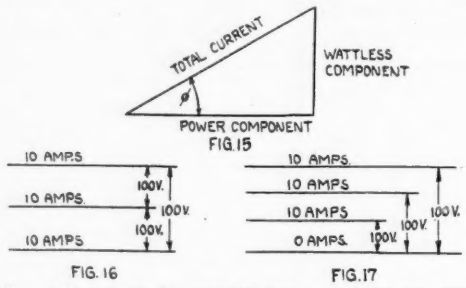


FIG. 15. GEOMETRICAL RESOLUTION OF CURRENT INTO ITS RESPECTIVE COMPONENTS

FIG. 16. DIAGRAM SHOWING CURRENTS IN A 3-PHASE CIRCUIT

FIG. 17. THREE-PHASE, 4-WIRE SYSTEM

part of it in overcoming friction. The pull on the traces may thus be said to consist of a friction component and a gravity component, and yet these distinctions are imaginary as the horse exerts his pull in one direction only.

In a 2-phase circuit, which really consists of two single phases, the power is expressed thus (assuming phases to be equal).

$$\text{Kw.} = \frac{V \times A \times \text{P.F.} \times 2}{1000}$$ where V and A are the voltage across each phase, and the current in each phase respectively.

In a balanced 3-phase circuit the formula becomes

$$\text{Kw.} = \frac{V \times A \times 1.73 \times \text{P.F.}}{1000}$$ when V = voltage across any pair of line wires, and A the value of the current flowing in them. Thus in Fig. 16 which has 10 amp. per leg or lead, and 100 v. across each phase the power would be

$$\frac{100 \times 10 \times 1.73 \times \text{P.F.}}{1000} = 1.73 \text{ P.F.}$$

In this case 1.73 would be the kv.a. which, multiplied by the P.F. would give the kw.

The deviation of the above formula is simple but will not be given in this article.

In a balanced 3-phase, 4-wire system the power becomes

$$\text{Kw.} = \frac{\text{Volts to neutral} \times \text{amps. in line} \times 3 \times \text{P.F.}}{1000}$$

Thus in Fig. 17 the power would be

$$\text{Kw.} = \frac{100 \times 10 \times 3 \times \text{P.F.}}{1000} = 3 \text{ P.F.}$$

Inasmuch as the voltage between line waves equals 1.73 times the voltage to neutral, the line voltage in Fig. 17 would be $100 \times 1.73 = 173$ v. This then agrees with the 3-wire, 3-phase formula given previously—simply using 173 for the voltage.

$$\text{Kw.} = \frac{173 \times 10 \times 1.73 \times \text{P.F.}}{1000} = 3 \text{ P.F.}$$

We will later on give further consideration to the meaning of the terms single-phase, two-phase, and three-phase as used in these formulas. We give herewith a tabulation that covers them and which will serve to make their relations to one another a little clearer.

1 ϕ $\text{Kw.} = \frac{\text{volts} \times \text{amps.} \times \text{power factor}}{1000}$

2 ϕ $\text{Kw.} = \frac{\text{volts} \times \text{amps.} \times \text{power factor} \times 2}{1000}$

3 ϕ 4-wire $\text{Kw.} = \frac{\text{volts to neutral} \times \text{amps.} \times \text{power factor}}{1000}$

3 ϕ 3-wire $\text{Kw.} = \frac{\text{volts} \times \text{amps.} \times \text{power factor} \times 1.73}{1000}$

Operation of Slip-Ring Brushes

CORRECT CARE AND MAINTENANCE OF SLIP-RING BRUSHES IS JUST AS IMPORTANT AS IN THE CASE OF COMMUTATOR BRUSHES. BY E. B. SHAND*

SLIP-RING brushes may be classified according to their characteristics as determined by the relative amounts of graphite and metal in their composition. There will be, of course, no distinct lines of demarcation between the classes but the following general terms may be applied —carbon or graphite brushes, metal-graphite or metallized brushes, and semi-metallized brushes.

In the first type are included practically the same brushes as are used on commutators. They are applied where low current densities can be maintained regardless of the collector ring speed. The maximum permissible density is only slightly in excess of that used in commutator practice, and in numerous cases may be even lower. This type of brush is ordinarily used on the slip rings of synchronous machines, on small wound-rotor induction motors, small synchronous converters, and small synchronous generators of the revolving armature type.

Metal-graphite brushes have a high metallic content, which is largely copper, and an amount of graphite which serves as a lubricant. These brushes will operate with much higher current densities than the graphite brushes and often at lower temperatures. A large part of this class has insufficient lubricant to prevent the abrasive action of the brush at ring speeds above 3000 ft. per min. These metal-graphite brushes are used on induction motors and synchronous converters.

Semi-metallized brushes may be considered an intermediate class between the other two. These brushes have an appreciable metal constituent but an insufficient amount to make them predominantly metallic in their characteris-

*Power Engineering Dept. Westinghouse Electric & Mfg. Co.

tics. They usually have a tendency to polish the ring in common with graphite brushes but permit somewhat higher current densities. It is noticeable, however, that the brush temperature tends to rise considerably with these higher current densities. These brushes have been used for special applications covered by both of the above classes of brushes, which will be mentioned later.

Actual current densities allowable for these various types of brushes will vary considerably, depending upon the particular conditions in the machine considered, and is really a design problem. It is important to note, however, that brushes of lower carrying capacity should not be substituted for a grade originally furnished except in special cases. The catalogs and data books of brush manufacturers give recommendations regarding the limiting current densities. It is desirable, however, to keep well within the upper limits of current density, as the operation will be more satisfactory when the brush is applied conservatively.

From the standpoint of brush maintenance, the following precautions should be taken. The brush should fit properly in the box and not stick. Cases have been found where brushes have been too large and others where dust has penetrated between the brush and the box, causing sticking. At periods of inspection every brush should be worked up and down in the box and the machine not put back in service until all brushes slide freely. The spring tension on all brushes of the same ring should be uniform, otherwise the current will not be evenly distributed—the brushes with the greater spring tension will tend to take more than their share of the current. In such cases it has been found that certain brushes carry several times the average value and the resulting overheating may permanently injured them. Experimental work on metal graphite has indicated that the proper spring tension should be about 2.25 lb. per sq. in. of contact surface. In actually measuring this tension, corrections should be made for the weight of the brush according to its position on the ring. The brush boxes should be lined up properly on the rings and from $\frac{1}{8}$ in. to $\frac{3}{16}$ in. from them. If a brushholder is imperfectly centered, so that a part of the brush overhangs the edge of the ring causing a lip to form on the brush, the rate of brush wear and the dusting increases. If it is impracticable to avoid this condition, the overhanging edges of the brushes should be kept carefully bevelled off as shown in Fig. 1.

Care of the rings is quite as important as that of the brushes, and many cases of trouble can be attributed to the lack of this care. A ring which is rough or eccentric will prevent good contact being made. This is particularly true of rings which operate at high peripheral speed. Vibration will naturally produce similar results. Rough or eccentric rings should be turned or ground, and causes of vibration should be eliminated. Even in the best balanced high-speed machines the vibration is sufficient to cause appreciable variations in contact pressure, and for this reason it is standard practice to employ not less than two brushes on any ring placed at different points on the circumference. If any one brush tends to leave the ring, the others may remain in contact to carry the current.

Where direct current is used for the excitation of synchronous machines, it has been found in some cases that there is a tendency for one ring to pit; this usually occurs at one or two points on the periphery. Practically all cases of this kind have been reduced to imperfect contact conditions between the brush and ring, either from vibration or from the ring not being perfectly true. The pitting is the result of arcing at the point where the brushes leave the ring. The trouble may be reduced somewhat by reversing the current occasionally, but to prevent its recurrence the mechanical conditions should be corrected. It has been found that this tendency is much less for metal-graphite brushes than for carbon brushes and in consequence the carbon brushes on the rings of synchronous condensers, etc., have been replaced in a number of cases with a semi-metallized brush with a great improvement. Trouble of a somewhat similar nature has occurred on small induction motors and synchronous converters furnished with carbon or graphite brushes, as is often indicated by burned streaks on the ring surface due to sparking. Semi-metallized brushes may prove the solution in these cases as well.

Perhaps the most severe service required of collector-ring brushes is on the larger synchronous converters. The amount of current to be collected is at times great and the collector speeds are high, particularly on 60 cycle machines. These two conditions require a brush of high current-carrying capacity, yet one which will not cut the rings excessively. Experience and experimental investigation have shown that the range for brush characteristics is somewhat narrow and fairly well defined. A metallized brush, in general, gives most satisfactory service.

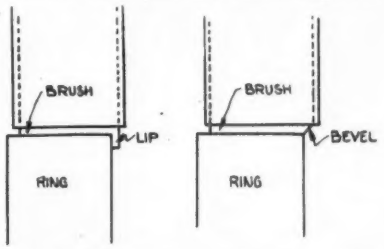


FIG. 1. OVERHANGING LIP ON BRUSH AND METHOD OF BEVELLING

On account of the particularly severe conditions imposed upon brushes in the last mentioned application, their proper care becomes perhaps even more important than that of commutator brushes. One trouble has been found in the overheating of certain brushes which may often be traced back to unequal spring tensions resulting in a non-uniform distribution of current between brushes. The spring tension is, therefore, an important point in maintenance and to facilitate this, a brushholder has been developed with a thumb-screw tension adjustment, as shown in Fig. 2. The ideal condition for a commutator is generally accepted to be indicated by a dark brown glazed surface. There has often been a tendency to use graphite or semi-metallized brushes on converter rings to obtain a similar result. It may be said, however, after a considerable amount of experience and testing, that these types of brushes have not been found suitable for severe service. The brushes, while they produce the glazed surface, will have inherently a high voltage drop at the contact surfaces and high losses, the effect of which will be quite perceptible on the efficiency of the lower voltage machines. In addition to the much higher average brush losses, it has been found that these types of brushes are more susceptible to unequally distributed currents than the metal-graphite grades, so that losses in a portion of the brushes on a machine may be great enough to cause temperatures beyond

safe limits. Oxidized or burnt shunt connections and brushes stuck in the holders, due to high temperatures or arcing, are frequently found where these brushes are used. On the other hand, a metal-graphite brush operating under good conditions should remain comparatively cool and the ring should assume the natural bronze color, but without a raw appearance. Rings much grooved should be ground; otherwise severe ring cutting is liable to occur.

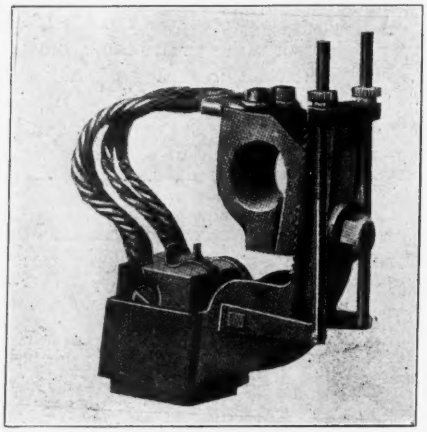


FIG. 2. BRUSHHOLDER WITH THUMB SCREW ADJUSTMENT

Another contrast between commutator and collector-ring operation is that of sparking. It is impracticable to eliminate sparking from commutator brushes entirely and furthermore, when this is slight, its ill effects are negligible. With collector-ring brushes any sparking must be regarded as serious. With metal-graphite brushes, sparking has the tendency to burn out the metal from the contact surface leaving the graphite, as a result of which the voltage drop may increase to several times its normal value. The losses increase and the current distribution becomes disturbed so that the effect is more or less cumulative. Cases of this sort have been found where the operation of some of the brushes of a machine has been seriously impaired, or even where their effectiveness as brushes has been entirely destroyed.

When sparking, or even evidence of certain brushes getting hot, is first observed, all brushes should be inspected, and any of them exhibiting a blackened contact surface should be scraped until the original brush color again appears. Precautions should be taken to prevent any recurrence of the trouble by improving the ring surface and equalizing the brush tension. It may be mentioned that this effect varies considerably in various grades of brushes; in some it is practically negligible while in others it is serious.

In the case of induction motors of the larger sizes, a metal-graphite brush similar to that used on synchronous converters is extensively employed at the present time, although the service is not so exacting and a greater range of characteristics is permissible. There are, however, many machines in service with brushes of the semi-metallized class, from which good operation has been obtained. The ring speed for induction motors is ordinarily much lower than for 60 cycle converters, and it is usually possible to operate the brushes at considerably lower current densities as well. For these reasons the service on these machines is much less severe and the same amount of care is not generally necessary to obtain satisfactory operation. Brush trouble may be found occasionally when a motor is located in a very dusty spot, where inspection and cleaning may be largely neglected. Such conditions should be taken care of as well as may be permitted by local conditions—The Electric Journal.

Voltage Control of Transmission Lines

PAPER DELIVERED BEFORE THE A. I.E. E. DISCUSSES REQUIREMENTS OF EQUIPMENT TO REGULATE VOLTAGE PROPERLY. BY JOHN A. KOONTZ, JR.

IT IS GENERALLY conceded that the long high voltage transmission line is inherently poor as regards voltage regulation. The inductive reactance is high, due to the wide spacing of the wires required for the high voltage and transformers must always be considered with the line when voltage regulation is concerned. The wire must have a large diameter to avoid corona loss but, in general, this conducting material of the large cables is utilized to advantage in keeping the energy loss at a low figure. These cables, however, subjected to a high voltage, cause heavy charging currents to flow.

With these points in mind, namely, a system of high reactance, which at no-load carries a heavy charging or leading current, it is readily seen that the voltage generated by the flow of this current through the inductive reactance is added to the impressed voltage and thus the receiver voltage on the long transmission line is higher at no-load than the generator voltage. The amount of this rise in receiver voltage at no-load will naturally depend on the design of the line and connected transformers, but with present 100-kv. systems this value may be as much as 8 per cent above the generator voltage, and the highest voltage lines met with may have an increase in voltage of almost double this amount under no-load conditions.

In practise the load met with is almost universally of a lagging nature. When this load with its lagging current is carried by the transmission line, we meet with the reverse conditions to that of an empty line with charging current, as the e. m. f. generated in this high reactance system when carrying lagging current, opposes the generator voltage, and the drop between generator and receiver ends of the line becomes quite excessive at low power factor and heavy load.

EFFECT OF POWER FACTOR ON TRANSFORMERS AND LINE CAPACITIES

To show this effect of power factor on transformers and line capacities, figures from an actual curve will probably best serve the purpose. These results cover conditions as obtained on 190 mi. of 160-kv., three-phase circuit. When maintaining the same generator voltage and a constant receiver voltage, we could transmit over such a line:

At unity	power factor	...60,000 kw.		
At 90 per cent	" "	...35,000 "	(current lagging)	
At 80 per cent	" "	...28,000 "	"	"
At 70 per cent	" "	...21,000 "	"	"

From these figures it is seen that by change of power factor we can readily control the voltage to suit load con-

ditions, and this is the method used on long lines, for in the first place it is an economic necessity to provide ample synchronous condenser equipment in order that the lines and transformer equipment may operate at near unity power factor, and it is a simple matter and of relatively small expense to provide the necessary regulator equipment in order that the voltage on the receiver system may be held constant and the power factor shifted to suit load conditions. The ordinary regulator of the Tirrill type is well suited for such work if the equipment is of the so-called broad range type such that it will control the field current of synchronous condenser or generator from practically zero to a value well above normal.

In some transmission systems where the ohmic resistance is low and the reactance high, it is possible to operate with equal and constant voltage at both ends of the line, but in most cases it is necessary to operate with the generator voltage higher than the receiver. The amount naturally depends on the size and length of line. In general this generator voltage should exceed the receiver voltage by at least the resistance drop of the load current in the connecting lines, and sometimes more than this value, depending on the power factor of the load that must be handled over the line.

In order to reduce the line losses, particularly at light load, line drop compensators can be used on the generator voltage regulators to advantage, as by proper setting of these power house regulators, they will increase the generator voltage as the load increases to take care of the line drop, and at light-load or no-load the voltage will be automatically lowered so that the receiver condensers will not be called upon to supply such large amounts of lagging line current at light loads. These line drop compensators will not only increase light-load losses but will also permit of use, in general, of condensers which are of slightly less cost, as a condenser will probably only have to supply one-half or less of its rating in lagging line current at no-load conditions.

Generator Design

In order that satisfactory voltage control may be had in connection with any high-voltage lines, the apparatus must be specially designed to suit conditions. The generator design must be such that the units will carry charging current without becoming self-exciting, or such that under all operating conditions, these units will require positive field excitation to give their normal voltage at normal frequency. When practicable, these generators should be of such size and so designed that one unit will charge a transmission line. This will not always be possible in connection with the extremely high-voltage lines, but where a single unit cannot be used, the station, or certain groups of machines in the station, should be designed to take care of line charging and testing, so that this may be handled with dispatch.

The synchronous condenser should be selected so that they will furnish their maximum kv.a. of lagging line current with field excitation above the residual voltage of their exciters. Condensers that are operated from the secondaries of transformers or tertiary windings of auto-transformers where power is not supplied from the same winding or from the condenser bus, should be carefully selected for operation with their respective transformer designs, so that the voltage variation obtained, due to power factor changes through the transformers, will not affect the condenser output. It must be borne in mind that the condenser will have to furnish its highest voltage at a time when it is operating with its heaviest field current, or when furnishing leading line current, while on the other hand, when furnishing lagging line current and extremely low fields, the condenser will in turn be operating at well below normal voltage. This may affect the kv.a. output of the machine or reduce the field excitation to such value that it is difficult or impossible to obtain stable regulator operation. This variation in voltage in modern transformer design, may easily amount to 15 per cent.

Voltage regulation of long lines is thus taken care of mainly by power factor control. The synchronous condenser not only serves to correct the power factor and in many cases reduce line losses but it also gives a steadying effect on the system, which is difficult or impossible to obtain by any other method of voltage control. Short lines can be operated without condenser equipment but it is difficult to obtain good voltage regulation by generator regulators alone when the load power factor is poor. For satisfactory operation of long lines it is essential that automatic voltage regulators be used at both generating stations and on the condensers at the receiving stations, and in general line drop compensators can be judged to advantage in connection with the generator regulators.

Pipe Insulation for Lines Underground

RECENTLY the Pacific Gas & Electric Co. started on the installation of 1300 ft. of insulated underground steam pipe which leads from their steam plant to various buildings and apartment houses in San Francisco. The insulating jacket was 2 in. in thickness with a water-proof roofing felt on the outside. The inside of the layer of insulating material was lined with polished 4x dairy tin which gave added efficiency to the covering.

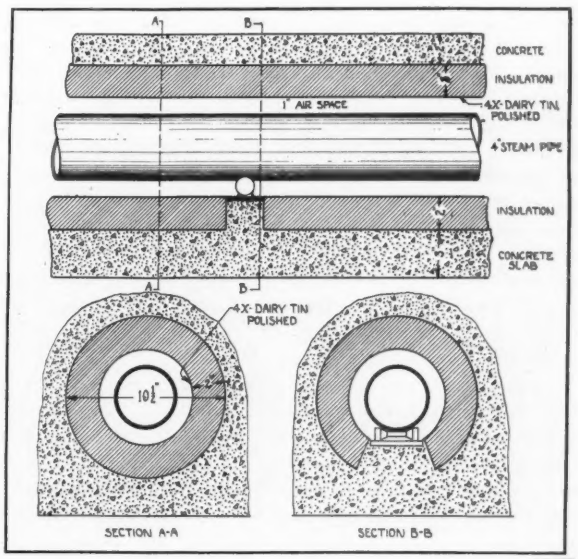


FIG. 1. SKETCH SHOWING METHOD OF BUILDING UP INSULATION

One inch of air space was left between the steam pipe and the inside of the covering to permit the steam pipe to expand or contract freely without rubbing, and also to obtain a larger insulating surface. The steam pipe was supported on rollers every 20 ft. to allow of expansion and contraction.

In this installation the first step was to lay a 3-in. layer of concrete in the bottom of the trench. The

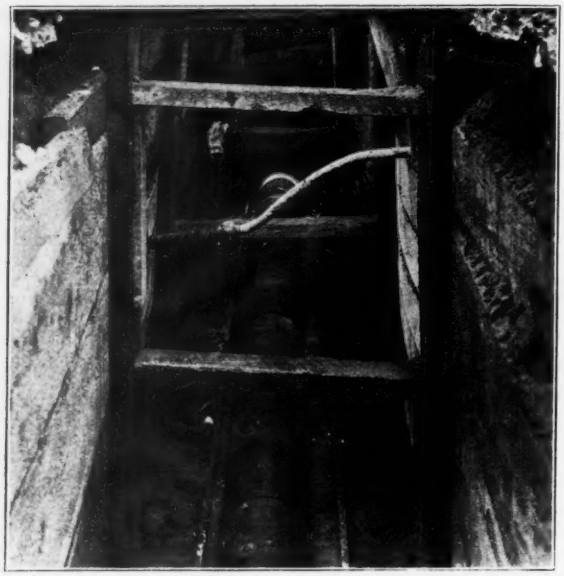


FIG. 2. VIEW OF INSULATED PIPE READY FOR CONCRETE COVERING

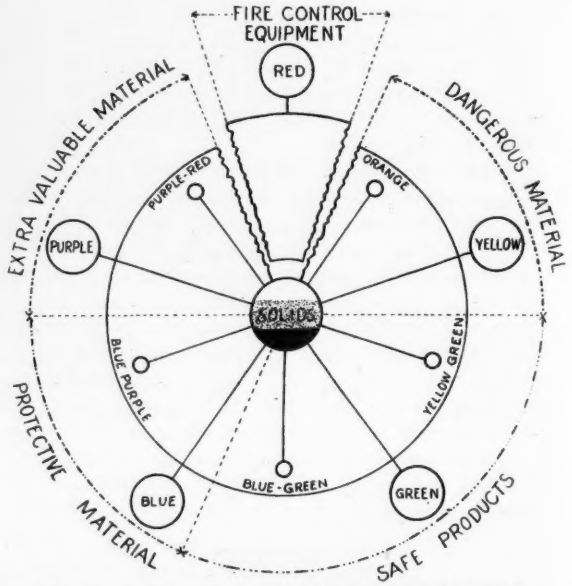
outside diameter of the pipe shown in Fig. 1 is 4½ in. The 3-in. slab layer of concrete was about 18 in. in width, with the roller bases secured to concrete footings. The steam pipe was laid in the trench and the insulating covering slipped over it as it was laid until a point was reached where it was more convenient to install the covering in half sections. At the points where the rollers support the steam pipe the lower portion of the covering was cut away, allowing the weight of the pipe to rest on the concrete foundation. When the installation of the insulating material was complete, the bottom of the covering rested on the 3-in. layer of concrete. Concrete was then poured over the entire installation to about 2 in. in thickness.

The insulating value of the covering is extremely high. The fact that the insulation itself will not disintegrate under repeated saturation with water, and the ease with which it is handled make an extremely economical, efficient, and durable method of insulating underground steam pipes. The patented insulating material is made of calcium sulphate and other materials in powder form. This is mixed with water and poured into forms or molds where an effervescent or chemical action takes place, forming a myriad of small air bubbles, each separate from the other. In this stage of manufacture, the mixture has expanded to three times its original volume, consisting of two-thirds dead air and one-third solid matter. After having been poured into molds, the expanded mixture sets quickly and is then withdrawn from the molds, after which it is allowed to dry for three or four weeks.

Identification of Piping Systems by Colors

SOLAR SPECTRUM SUGGESTED AS THE NATURAL BASIS FOR A COMPLETE COLOR SCHEME IN TENTATIVE REPORT BY SUB-COMMITTEE ON IDENTIFICATION BY COLORS OF THE A. S. M. E.

FOR QUITE a long time, pipe lines have frequently been painted in different colors for the purpose of ready identification. Of the various color schemes heretofore devised none has been based upon any definite fundamental principle. Because the selection of colors has been arbitrary and influenced by local conditions not common to plants in general and because a comprehensive extension of such schemes soon involves a mass of detail which automatically renders them difficult if not impracticable, the



EACH SPECTRAL REGION REPRESENTS A MAJOR PIPING CLASSIFICATION

inadvisability of recommending any of them for adoption as a universal code is fairly obvious.

It is obvious that to attempt to outline a code in which every product liable to be transported would have its identification, would result in a system so comprehensive that even should the supply of colors and identification symbols hold out, adoption of it would be automatically rendered impossible in those industries which do not have a major group of colors allocated to its products. It is found, however, upon investigation that any materials transported in pipes in a plant fall in one of the following classifications:

Safe products—this represents a majority of the products that are handled through a plant. Those products may be defined as having no hazard in their handling and no extraordinarily high value, so that a workman in approaching a piping system to make repairs will run no undue hazard in breaking into a pipe bearing a safe material, even though that material had not been emptied by previous arrangement.

Extra valuable material—this might be classified as a part of the safe materials above mentioned but inasmuch as cases exist where those products would have a very high

value, it appeared preferable to give them a separate major classification.

Dangerous materials—these materials are those which inherently in themselves are hazardous to life or property by virtue of being easily inflammable or productive of poisonous gases or are in themselves poisonous. They include, of course, materials that are known ordinarily as fire producers and explosives.

Protective materials—under this class falls materials which are piped through plants for the express purposes of being available to prevent or minimize the hazard of the dangerous materials above mentioned. Thus, a plant may have certain special gases which are antidotes to poison fumes, which gases are piped through their plants for the express purpose of opening or breaking the pipe in case of danger.

Fire control equipment—this might properly be called a division of the protective materials just mentioned above, though the hazard of fire and the use of sprinkler systems and other fire fighting equipment having become so universal, it would appear better to make it a special major classification.

In any complete color scheme of this sort the natural basis is the solar spectrum, and if the spectral hues are arranged in their natural order in the form of a circle this article may be divided into five sectors, each sector or spectral region representing one of the five major classes and capable of subdivision, where necessary, into a larger number of hues having approximately similar dominant wave lengths but distinguishable from each other under favorable illumination.

Visibility at less than ordinary illumination is obviously an important item and it has been given full consideration. Without a certain amount of illumination from a source of light which includes at least some of all the visible wave lengths found in ordinary daylight no complete system of identification by color can operate. It becomes necessary, therefore, to establish some arbitrary minimum limit to the amount of illumination required. As a test for this minimum an ordinary hand flashlamp may be used. It is not yet decided as to the best methods of standardizing the lamp or the distance at which it can best operate.

With regard to durability there seemed at first to be a general idea that the five or six indestructible pigments could be selected and paints made from these only. A little reflection soon shows a position of this sort to be untenable, first because the resistance to attack is limited by the vehicle as well as by the pigment: second, there are few substances either in the inorganic colored pigments or the organic vehicles that are equally immune to all the various forms of attack and third the commercial availability of the materials from which practical and economical paints can be made is by no means a negligible factor.

This system as suggested seems to lose sight of some important facts in economical paint production, facts which have heretofore taken a paramount position in the painting of iron and steel where the protection against corrosion has been of equal or greater importance than the color of the coating.

Black, for instance, has been widely used, not only because it may be made at a low price but also because it is practically the only paint that will withstand elevated temperatures without discoloration, has a relatively longer life under direct exposure to sunlight and in the form of asphaltic varnishes is proof against all acids, alkalies and sulphide sulphur compounds even in relatively strong concentrations. It is the ideal paint for pressure steam pipes but the position has been taken that in most modern plants such pipes are insulated by various kinds of covering mostly white or nearly so and in general not in need of any kind of paint. Such pipes may still be painted black as protection against corrosion and the covering is best marked for identification by letters, symbols, or signs.

Metallic browns and other types of red oxide of iron have also been very largely used in low-priced anti-corrosive paints. While the reflective value of the higher qualities of Venetian red is 19 per cent or better, the darker shades run somewhat lower, and for this reason it is believed the dark browns may be excluded from the system with less sacrifice than attends any attempt to retain them.

Aluminum paints also are useful in many cases. As a pigment it does not work very well in oil varnish vehicles but in pyroxylin varnish it works much better. According to the suggested system valuable materials fall in the purple sector but there seems to be no inherent obstacle to including the aluminum in this class if it represents something of extraordinary value. Gold bronze powders are of no especial value and may be omitted without economic loss, but if included for any special reason would fall in the yellow or dangerous sector. Whites and grays have not been emphasized because in the early conception of the system these achromatic colors were reserved for pipes containing solid materials not subject to flow, specifically conduits carrying wires of any sort.

Boiler Cleaning

By F. S. Rutledge

THIS is a subject about which comparatively little is ever said and less written. It is usually considered, in a great number of plants when there are only one or two

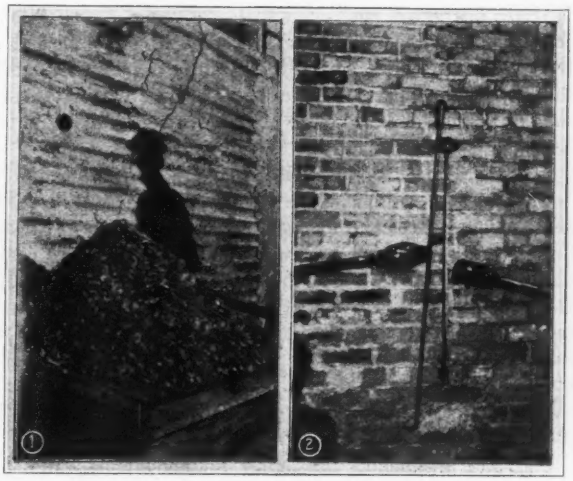


FIG. 1. SCALE REMOVED AFTER IT WAS REPORTED CLEAN
FIG. 2. TOOLS USED FOR CLEANING RETURN TUBULAR BOILERS

men, usually a fireman and engineer, or one man as a combination of both, as a dirty bothersome job, to be done as rarely as possible, just so they can get by and keep running.

In one plant, where the engineer was well along in years and really getting paid for what he had done, instead of

what he was doing, the boiler washers went through the motions and fooled the chief, as he was not able to get into and inspect a boiler any more. They began to have endless trouble with leaky tubes, bagged sheets, etc., until one of the boiler makers, who had known the chief for years, told him what the matter was. An assistant who was young and ambitious was hired and made responsible for the condition of the boilers. Before he had been on the job 60 days, one boiler was cut out entirely and the load carried on two with less fuel than formerly used.

I contend that boiler cleaning is, and should be, one of the most particular jobs around a steam plant. As an example of what can be done and conditions that may exist under the most careful cleaning, I am sending a picture of a 107-lb. pile of scale that was taken out of a boiler, after it had been washed out and inspected and reported in exceptionally good condition, as to cleanliness, for a power boiler. As far as could be seen it was, but a flue rattler got it out from between the tubes where it could not be seen or washed out with an ordinary hose and nozzle.

In Fig. 2 are some of the cleaning tools I use. There is a scraper for scraping between the tubes to get the scale off, a special nozzle for washing crosswise between tubes, a flue rattler for jarring off scale, both on water and fire side of tubes and a flue cleaner that is about the only kind that I have ever used that will work satisfactorily in welded tubes. Boiler compounds are a help in reducing the amount of scale deposited in the boiler, but I never have found any that would keep all the scale out and some kinds were worse than nothing.

Profits from Feed Water Treatment

By Howard S. Mead

THOSE who are connected with the practical operation of the power house are in a position to appreciate the vital importance of installing water purification and similar systems, as they alone have learned to measure its value in terms of breakdowns and the expenses incident to its neglect.

Practical men fully realize the dangers of boiler shutdowns, clogged-up lines, condensers, etc., as well as the tube replacements necessary under a regime where an installation of this sort does not obtain. But while they are convinced of the desirability of the new equipment, quite likely they are resigned to an attitude of the uselessness of attempting to purchase it. In other words, they are not salesmen enough to sell the idea to their superiors. Their attitude may be summed up as that of an "order taker" who says, "Now I would like to have you do this, because I want it; it will help me out greatly."

As an argument, this patter sounds almost childish. If you want water of "zero" hardness badly enough, at least sit down and make an outline of the values accruing from its use, vizualize the savings to be made in hard cash—the dollars and cents value; as this is the sort of thing that appeals to a man who is interested in running a factory. Finally, put the matter before him in a straight forward talk, based on an economical, money-saving basis. Placed in this light, the proposition naturally assumes an increased importance, one worthy of attention, immediately, rather than in the dim, hazy, far-off future.

An instance which forcibly illustrates the point in question occurred in a plant equipped with eight 500-hp. Stirling boilers only recently. The power house superintendent realized the vital need of a good water softening system, but was unable to put his case "across" sufficiently strong to cause the management to act favorably.

It must be said that the scale solvent in use was giving particularly effective results, and comparative freedom from operating difficulties was had, as a consequence. This fact combined with the initial investment involved quickly precluded any chance of ordering the new equipment. But after the third turn-down, our friend, the superintendent, decided to give the works manager a real, honest-to-gosh combined argument and exposition on the necessity and why-for of the new system, and discarded the "I want it—I need it" plaint.

First, he covered the principles of the system, explained its ability to keep the operating apparatus clean permanently. All of us know that scale forms one of the most common and distressing difficulties in the entire operation of the power plant; but it is rarely that others know about the degree that it enters into practical operating problems. He exhibited, then, a cut-off section of one of their own pipes—which, by the way was one of the worst that he could locate—and stressed the fact that there were a good many other lines on the plant which were in nearly as bad shape.

Mr. Manager began to get interested in the subject. Why, he really hadn't begun to appreciate the shape his pipe lines were in.

Our friend seized the opportunity to pound home a few more facts. He explained the operating principles of the new system; how a chemical reaction wherein sodium was exchanged for the calcium and magnesium in the water, formed the basis of the process. The fact was also stressed that the chemical bed used could be operated for years without deterioration.

Having pounded home the simplicity of the entire thing, he brought some figures into play as his final, trump card. He had prepared a tabulated summary of the various items entering into his estimated saving of approximately $8500 a year on the new installation. His notations read as follows:

Cleaning boilers and feed water heaters, two men	$2,400.00
Cost for tube replacements	75.00
Cost of gaskets for manhole and handholes	50.00
Fuel waste, due to scale (3% of yearly fuel bill)	6,000.00
Cost of boiler compound for year	1,890.00
or a total of	$10,490.00

for operation without the water softening outfit.

He then summarized the cost of operation with the water softener for a year, as follows:

Labor cost of attention to softener	$ 182.00
Cost of chemical treatment on approx. 150,000 gal. of water per day	1,350.00
Interest on investment (about $5500.00)	330.00
Depreciation on equipment	275.00
or a total of	$2,137.00

In this form, the information could be had almost at a glance and was so convincing that the manager was quickly sold on the idea of buying a water softener. No doubt, our friend had a picture which was a little too rosy in the results to be obtained; but viewing the subject conserva-

tively, it would be found that the savings and economies brought about would be sufficient to pay for the softener in a short period, 2 yr. at the most. I should say. Actual experience has taught the truth of this statement.

Many executives are not convinced easily as to the desirability of buying equipment of this nature; however, a good share of them have grown wary of grasping at the bait which promises excessive savings and are giving a correspondingly increased consideration to the modest savings made possible by a sane, common-sense change of operating equipment—savings which do not partake of the fantastic and far off; which they are able to see without the aid of a telescope.

Professor E. C. Schmidt, of the University of Illinois, prepared a table which will enable the reader to determine the fuel waste resultant from the formations of scale. This table will be found to meet all practical needs.

Conscientious engineers, by far in the majority, are no longer looking for the easiest way out. Softening equipment may present some little difficulties in order to install and a few may follow the easier path such as those who are behind the times, or who are not interested in the money saving; but the great majority are progressive enough to want to make the power house a paying proposition, to make money for the employer. The great trend is to cut down waste and inefficiency in these post-war days and practical men can do their share only by seizing every opportunity to increase operating efficiency and cut down maintenance costs.

FUEL WASTE DUE TO SCALE

Thickness of scale formation	Loss of Efficiency	Coal Wasted Per Ton Fired
1/50 in.	5.4%	108 lb.
1/32 in.	7.2%	144 lb.
1/25 in.	9.3%	186 lb.
1/20 in.	11.1%	222 lb.
1/16 in.	12.6%	252 lb.
1/11 in.	15.0%	300 lb.
1/9 in.	15.9%	318 lb.

Overhauling the Absorption Ice Machine

With the Exercise of Care and Judgment the Entire System Can Be Thoroughly Cleaned and Overhauled. By H. A. Cranford

THIS IS THE time of year when most engineers will be given the time to overhaul the plant. The first move when undertaking this work is to secure enough anhydrous cylinders and aqua drums from the ammonia company, from which you purchase your ammonia, to hold the entire charge. This will vary, of course, with the different size plants and the different quantity and quality of the ammonia charge in each separate plant.

Place one of the anhydrous cylinders on a good pair of platform scales and connect it to the valve in the bottom of the anhydrous receiver and weigh the cylinder to get the tare weight. Turn steam on the generator and distil off the anhydrous ammonia until the receiver is about full. Then turn it into the cylinder, drawing off an amount that will not exceed the net weight shown on the tag on the cylinder. It is a good plan to follow the ammonia with the scale until there is only about 75 to 80 per cent of the amount the cylinder is supposed to hold safely. Then attach another cylinder and repeat the process until the aqua ammonia in the generator is very weak. While this distilling process is going on keep the pump running with all pump out valves open until the system is relieved of all possible anhydrous. This should be done without building up the generator pressure above 200 lb. Continue running the pump until there is a vacuum on the absorber, then connect a hose from the absorber purge line to a barrel about half full of clean distilled water. With the pump running, this water will be sucked through the absorber, through the exchanger and into the generator so as to wash out nearly all the fumes of ammonia in the absorber.

Draw Distilled Water Through Dehydrator

Next shut off the absorber and let it stand and then pump a vacuum on the condenser and dehydrator. To do this shut off the main gas line valve from the generator to the dehydrator and also the valve in the line from the separator to the generator. Connect a hose line from a half barrel of distilled water to the dehydrator and draw a vacuum so that this fresh water will be drawn through the dehydrator, separator, condenser, anhydrous receiver and the pump to the generator. Allow the entire system to cool down for several days and while waiting for this go over every nut and bolt in the system with black oil cut with kerosene or gasolene.

When the generator is cooled, attach a hose to the clean-out pipe underneath the generator and set an aqua drum at a point lower than the bottom of the generator. This will allow the clear ammonia to run out without being agitated and accordingly the loss of ammonia will not be great. When the ammonia begins to show dirty change to another drum. Connect the hose to the discharge side of the pump and open the pump-out line from the generator to the pump suction. Run the pump slowly because the pump-out line is small and if the pump runs fast the liquor cannot reach the pump fast enough. The result will be the loss of gas at the discharge side and further the pump will agitate the liquor and cause sediment to be stirred up. After the generator is empty disconnect the flange where the discharge from the pump enters the generator and run a half barrel of distilled water through the generator.

Ammonia Should be Allowed to Settle in Drums

This process frees the system of nearly all fumes, and the work can be gone about with comfort and hardly any loss of ammonia. The ammonia should be allowed to settle in the drums and when it is being pumped back into the system, the pump should be run slowly. It is advisable to fix the suction pipe from pump to drum so that it will be impossible to pump out the bottom four inches of liquor. In this way no sediment goes back into the system. In some instances it may be advisable to ship the old aqua ammonia back to the ammonia people and get credit for its value. The system can then be re-charged with fresh aqua ammonia.

Inspection of the system should start with the absorber. Examine the tubes and if they show any pitting it will

be best to put in new ones. Tubes will seldom last more than 7 yr. except where the water is unusually good. It is often good practice to change the tubes every 5 or 6 yr., especially if the absorber is the double-pipe type. Use a scraper and clean the tubes thoroughly. If they are of the double-pipe type, see that the rubber packing rings still have life in them and show enough take up to last through another season. The dehydrator will show the greatest deterioration. Draw one of the inner pipes and examine it. If it has been in use 3 or 4 yr., it will have the appearance of having been through fire. There are few pipes to be replaced in the dehydrator and it is well to replace them every 3 yr. in order to avoid one going bad in the middle of the ice season.

Generally it is not necessary to go into the generator more often than once in 4 or 5 yr. Water can be pumped through it and a fair job of washing can be accomplished. It is advisable to repack all valves and reseat any that may require it. It is often found that pump-out valves are choked up with scale, grease and dissolved rubber from poorly fitted gaskets. Examine the rings and rod on the aqua pump and if the rod is worn very much it will be best to replace it with a rod made of high-grade tool steel. See that the valves are tight and the springs and gaskets are in good condition.

Expansion Coils Should be Cleaned

Next pull the cans and pump the brine out of the tank into the cans. Wash out the tank thoroughly, until all the loose rust and sediment has been removed. Scrape the two top pipes in the expansion coils and give them a coat of a good low-temperature paint. Pump the brine out of the cans back into the tank leaving about 3 in. of settlings in each can which can be wasted. The cans when emptied, thoroughly rinsed and dried should be brushed with a good stiff brush and painted from the top down about 15 in.

To recharge the system, pump the clean aqua ammonia into the generator until the liquor shows about 2 in. higher than the top row of steam pipes in the generator. Open the purge valve in the top of the absorber and insert it in a pail of water.

Pump aqua ammonia into the absorber until the normal liquor height is reached, during which time the purge line should be open to allow the liquor to displace the air in the absorber. Next turn steam on the generator and when the pressure reaches 100 lb. open the weak liquor line from the generator to the absorber, allowing the weak liquor cooler and exchanger to fill. The pump may then be started and when the pressure has reached 125 lb. open the purge line in the top of the condenser and turn the gas from the generator through the dehydrator. This will relieve the system of air up to that point. Then turn the ammonia into the anhydrous receiver, and open the pump-out line from the receiver through the check valve to the absorber.

It should be remembered that the circulating water should be running all the time; in fact, it is best to let the circulating pump be the last thing to shut down and the first thing to start. When all the air has been removed, put the machine in regular operating condition and purge it every few moments. Do not be afraid to purge, because if the purging is done in clean distilled water and if the water is changed often enough, there need be no loss of ammonia. After the machine has run a few hours, test the liquor and expand in anhydrous ammonia until the required strength is reached. Then if the quantity is not great enough, pump more aqua ammonia into the absorber and keep the purge line cracked open while doing it. Add aqua or anhydrous as needed until the quality and quantity is the desired amount. It will be necessary to continue the purging several times daily for about a week.

Operation of Underfeed Stokers

IN STARTING an underfeed stoker be especially careful not to get too heavy or too hot a fire on the ash plate. With some kinds of coal, it may be necessary to put the ashes at the lower end of the stoker, to prevent burning the ash plate. Always be sure that there is little burning coal on them. In case it is necessary to get the fire out of the furnace quickly, the best method is to close the air blast, leaving the stack damper open, open the dump plates, and deaden the fire with water from a hose, then push it into the ashpit, where it may be extinguished. Under no circumstances should the water be allowed to touch the brickwork. Do not keep the ash discharge open any wider than necessary to allow the ashes to fall through. It is best to keep it closed enough to maintain a bridge of ashes over the opening and a thick bed of ashes on the ash plates to protect them. If it is necessary to dump hot refuse, be sure to quench the fire in the ashpit. In the case of large clinkers that will not dump, it will be necessary to withdraw the ash support plate temporarily to let the clinkers through.

To bank the fires, shut off the air entirely, and push in coal until the required depth of bank is obtained, depending upon the length of time the stoker is allowed to stand. Do not use much travel on the side bars when banking fires. In banking fires, do not let them burn down to the tuyere plates or air box, as both may be injured. If the air box becomes badly cracked, it will allow fuel to get into it, which will burn and further injure the metal.

In starting from banked fires, turn on the air and start the side bars at their minimum travel. If the fuel bed is heavy, run the stoker with the hopper empty, without feeding fuel until the side bars have broken up the bed, and it has had a chance to burn to normal thickness.

With a new fire, the dump plate should be set with not more than 1 or 2-in. space from its end to the bridge wall. After operating for an hour or more, depending upon the rate of operation and the grade of coal, the ash plate should be opened about one section, or more, depending upon the conditions of the fuel at the back of the fire. After a period of 2 hr. open the same amount and repeat after another interval of the same length. By putting an extra stroke adjuster on the side bars, the tail end of the fire will be brought down into the ashpit. The time interval may have to be varied. The principle is that as a fire gets older, it also gets dirtier, hence a gradual opening of the ash-plates with a corresponding discharge will keep a practically clean fire. There should then be no piling of hot fuel near the bridge wall to cause clinker. The side bars should always have at least one stroke adjustment, to obtain ideal cleaning conditions. Clinkers sometimes

adhere to the side walls. Although stokers are automatic in the cleaning process, there are coals that form such clinker that it is desirable to resort to a bar with a chisel point to be driven between the clinker over the tuyere plates. Care should be exercised not to injure the side walls. Under some conditions, a slice bar for cleaning the soft clinkers and for breaking up the fire can be used to advantage. Shearing pins, that are easily replaceable, are provided so that if the ram becomes clogged, these will let go without serious damage to the stoker.

Per Cent CO_2 Obtained From Boiler Meter Charts

GRAPHIC COMPUTATION FROM METER READINGS GIVES EXCESS AIR AND CO_2. BY CHARLES E. COLBORN

NOT ONLY as a steam meter, but as a means for giving records of the excess air used in boiler operation, the boiler meter has been found to be a reliable instrument. The form of record of excess air given by this instrument is one that is valuable as a guide to the fireman, but is somewhat inconvenient to use in calculating the boiler losses. It is desirable for purposes of comparison and calculation to convert the Bailey boiler meter excess air records into terms of per cent CO_2 in the boiler gases. The accompanying chart is one that has been successfully used for this purpose. To determine the per cent CO_2, it is only necessary to know the air flow and steam flow readings as shown by the boiler meter and the per cent excess air when the pens on the particular boiler meter are together. This latter value is obtained by test. The flue gas of each boiler can be analyzed at different times when the hands have been brought together and from these gas analyses the per cent excess air can be obtained.

Tests should be made on all boilers to determine the per cent of excess air when the steam flow and air flow pens are together and the values obtained with each particular boiler used when the CO_2 in the gases from that boiler is being determined.

In many plants it will be found desirable in order to promote competition among the firemen to post records of the CO_2 obtained by the different operators on their shifts. These records can be obtained from the average steam flow and air flow readings for the different shifts by the use of the chart shown. Daily records of the CO_2 obtained in each boiler can also be obtained in the same manner. These records will be found of great value as a means of improving operating methods.

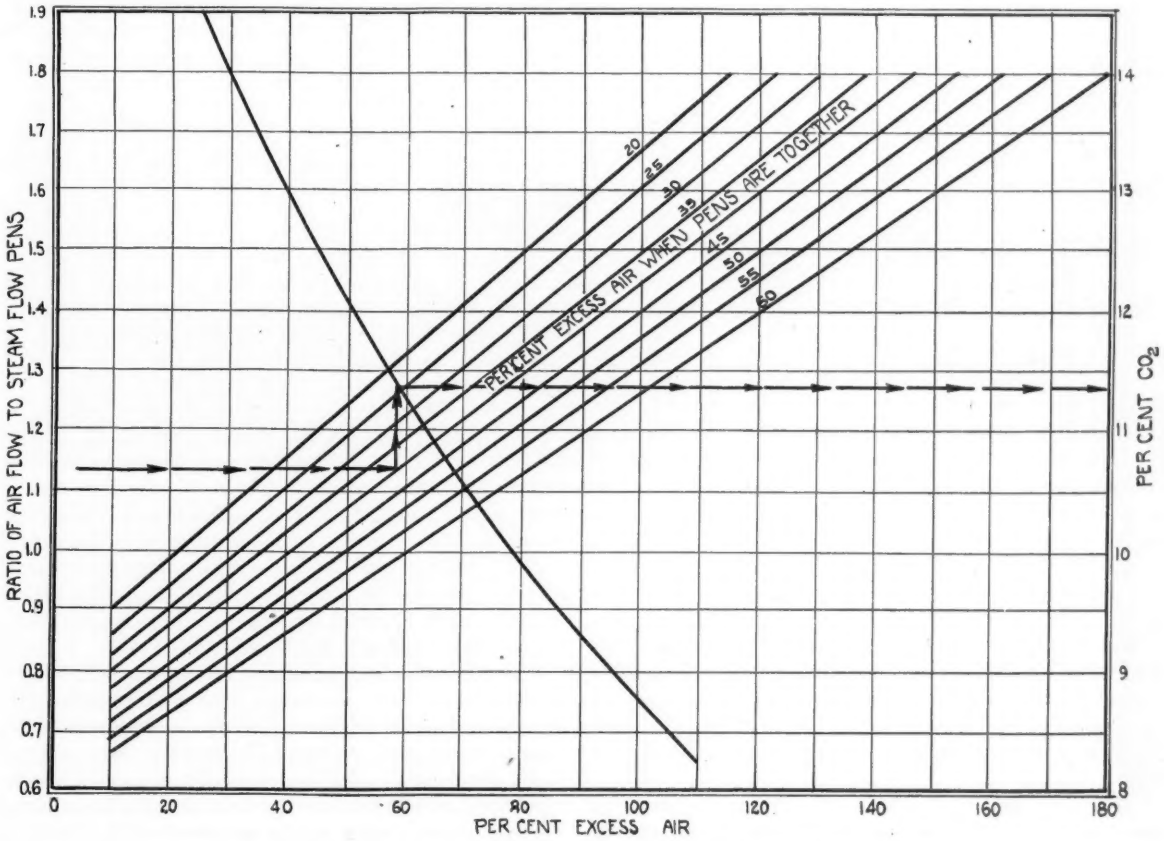


CHART USED TO DETERMINE CO_2 FROM BOILER METER READINGS

IN ALTERNATING current generators, the safe load expressed both in kw. and kv.-a., is a maximum when the power factor is unity. For a given kv.a. output the excitation current required for a 90 per cent power factor is approximately 15 per cent to 20 per cent greater than for unity, and for 80 per cent power factor, it is from 30 to 40 per cent greater than for unity. The field heating increases, and maximum safe load, both kw. and kv.a., decreases with the power factor.

Pulley and Shafting Problems*

By N. G. Near

TO ALINE shafting longitudinally an excellent way is simply to permit plumb bobs to be suspended around the side of the shaft as indicated in the sketch herewith. If several such plumb bobs are suspended in line, at least three of them, the millwright can merely glance along them and can see with his eyes whether or not the shaft is in alinement, and if the plumb bobs are far apart he can stretch a thread close to the vertical thread leading to the plumb bob and can measure the mis-alinement with almost perfect accuracy. The plumb bobs suspended in this way are all perfect tangents to the shafts and knowing the diameter of the shaft, there can be no question as to where the center of the shaft is all along the line.

On the other hand, in the case of alining apparatus that the writer has seen, the accuracy of the apparatus itself may be questionable, whereas with the plain suspended plumb bobs there can be no question at all. The simpler a thing can be made, usually, the better.

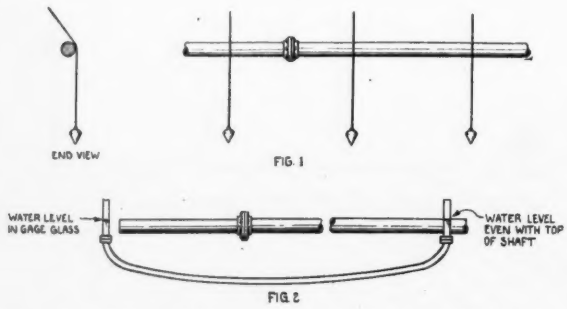


FIG. 1. SHOWING METHOD OF ALINING SHAFTING LONGITUDINALLY BY MEANS OF PLUMB BOBS

FIG. 2. ALINING A SHAFT VERTICALLY BY MEANS OF A HOSE FILLED WITH WATER

For alining shafting vertically, the writer does not know of a better method than the use of an ordinary garden or other hose filled with water, with gage glasses inserted in the ends, as indicated in Fig. 2. No matter how far the ends of this hose are apart, the water will always assume a perfect level and the millwright can be certain in a jiffy whether or not the shafting is absolutely level. The writer has seen this method used not only for alining shafting, but for laying foundations for machines and buildings and even for laying large floors. An absolutely level floor, foundation, or shafting is thereby assured.

Not long ago, in a prominent journal, the following questionable method was proposed for counterbalancing and balancing pulleys. The author said:

> "To counteract this extra weight, plant a bit of putty on the inside of the rim opposite the heavy side. By making a few trials with different amounts of putty at different points on the inside of the rim, the pulley can be brought to a good standing balance. Never try more than one pulley on the shaft at a time. When a balance is temporarily made in this way, remove the putty, weigh it and substitute permanent weight slugs in the form of one or more pieces of strap iron. The weights should be securely bolted in the middle of the inside of the rim, not to one side of the web, because this would impair or destroy the line balance."

Balancing by the foregoing method is not strictly correct, hence it is inadvisable, because of the difference in weight, of putty and iron per cubic inch. If putty weighed exactly as much as iron weighs per cubic inch and if the putty could then be molded onto the pulley exactly as stuck in place in the same form and in exactly the same position, without any additional weight due to bolts, nuts, rivets, or anything else, a perfect standing balance could be brought about. It is manifestly impossible, however, to do an accurate job in this way without considerable cutting and trying, because the iron slugs that will be bolted in place are heavier per cubic inch, consequently the mass is likely to be farther away from the center of the shaft and just as soon as the mass or weight is farther away from the center of the shaft, the pulley is sure to be thrown out of balance again. Also, in order to fasten the weight onto the pulley, bolts, screws, or metallic cement is required and since all of these things have weight and are heavier than putty, their respective weights must be given careful consideration, either mathematically or experimentally. To do an almost perfect job in this way requires much time.

If it can be done at all, a better way to balance a pulley is to follow a method given by the author of the foregoing quoted paragraph, as follows:

> "If a pulley is out of balance only slightly, it may be balanced by removing weight from the heavy side instead of adding weight to the light side—usually by boring one or more holes in the rim on the heavy side. Care must be taken, however, that the removal of this weight does not weaken the pulley."

In the opinion of the writer, the best way of all is a combination of the two methods described above. Use the putty method only "approximately" so that the slugs bolted to the pulley will be slightly lighter (not heavier) than the other side of the pulley. Then, to make the pulley balance, drill away a little metal from the opposite or heavier side and by cutting and trying a true balance is quickly attained. In this way, the strength of the pulley will not be impaired by excessive drilling or cutting and the desired balance will be found more quickly.

Another mistake commonly made by millwrights is to neglect the thickness of the belt when making pulley speed computation; belt thickness is often an important factor, especially on small pulleys. The smaller the pulley, the more important is the thickness. Thus, to find the correct speed of a belt in feet per minute, add the thickness of the belt in inches to the diameter of the pulley in inches and divide by 12. The result is the diameter plus the thickness in feet. Then multiply this by 3.1416 and then by the r.p.m. of the pulley and the result is the speed of the belt in feet per minute, assuming that there is no loss due to creep. In figuring a drive, or in other words, the revolutions that will be made by a driven pulley, this matter of creep and belt thickness must always be remembered.

The correction to be made for creep depends upon the belt. For balata belting, friction surface rubber belting, and stitched and filled canvas belting, the writer usually

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allows one-half of 1 per cent, and for solid woven cotton belting 1 per cent is allowed for creep. For leather belting it is proper to allow one-half of 1 per cent to 3 per cent, depending upon the load that is being transmitted. Creep depends entirely upon the elasticity and loading of the belt. Leather is more elastic than substitute belting, consequently a more variable allowance must be made.

New Gondola Car Dumper Used at Cahokia

NEW CAR DUMPER UNLOADS COAL CAR IN LESS THAN TWO MINUTES. BY E. H. KIDDER.

DUMPING a 50-T. car of coal in 1 min. 10 sec., with only one unskilled man and a 35 hp. motor— that is the feat being performed daily by the Gondola Car Dumper recently installed at the new Cahokia plant of the Union Electric Light and Power Co., St. Louis, Missouri.

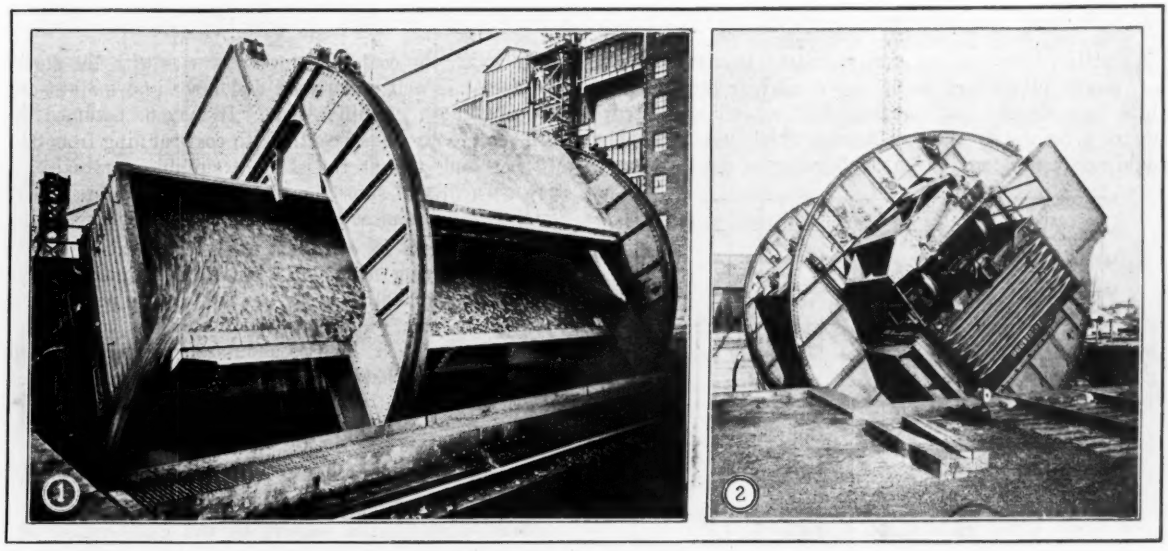
With only the first unit of the Cahokia plant completed at the present time the coal consumption averages but eight cars a day. Under the burden of eight cars a day, the continued operation of the dumper seldom exceeds 20 minutes.

From the mechanical standpoint, the mechanism, as is the case with any rotary type of car dumper, has three distinct functions to perform, viz: the rotation of the car through an angle which will permit the discharge of the material; support of the car on its tipping side; and the clamping of the car at the top. To perform these functions, the operator has but one controller handle to operate. This controller is of the drum type and while it provides speed control its primary function is the starting of the rotating motor. All other operations are cared for automatically by limit switches. The dumper is made up of two distinctly separate structures. One, that of the two roller rings, 24 ft. in diameter; the other being the transfer table or platen upon which the car stands.

This transfer table is carried on four rollers, two in the plane of each roller ring. The track for the rollers consists of four wedge shaped or beveled castings, attached to the under side of the transfer table. The bevel of these castings is such that the transfer table, with the car, would move over to the side support if it were not restrained. It is held in place, however, by two hook shaped castings fastened to the ends of the transfer table. Each of these castings engages a roller which is an integral part of the foundation.

As the dumper starts to rotate these hook shaped castings remain in contact with the rollers, serving as a retarding device for the transfer table; that is, there is a relative movement between the transfer table and the rest of the dumper, until the car has reached its side support. The angle of the beveled plates, which causes the platen to move towards the dumping side simultaneously with the rotating movement, is approximately 6 deg. and the distance of car travel from 6 to 12 in., depending upon the width of car.

With the return movement the reverse of these operations takes place. The car remains supported by the side structure until the hook shaped castings engage the rollers. After engagement, the continued rotation of the dumper causes a force or pressure to be exerted between the rollers and hook castings which is sufficient to push the transfer table up the slight incline made by the slope of the beveled supports and to aline the rails perfectly.



VIEWS OF THE LINK BELT CAR DUMPER AT THE CAHOKIA POWER PLANT

With the car in the normal position on the dumper, the controller handle is in the neutral position. To begin the cycle of operations, the operator moves the controller handle into the extreme forward position. Rotation of dumper and, as has been explained the movement of the transfer table, starts immediately. Upon rotating 10 deg., a projection (built on the side of one of the roller rings) operates a track limit switch, which in turn, starts the top clamp motor (10 hp.). This motor pulls the four top clamps downward simultaneously, until all four clamps have become firmly seated upon the top of the car and have exerted a predetermined pull on the operating cables.

When this predetermined pull has been reached it displaces an idler, which displacement operates a load switch thereby cutting off the motor and setting a high torque brake.

With the car firmly held to its dumping side and clamped at the top, the dumper continues to rotate until the rotating motor is automatically stopped by limit switches at the end of the rotating movement. Up to this time all the operator has done is to move his controller handle from the neutral to forward position.

He now moves his controller handle through the neutral position and into the extreme reverse position. This reverses the direction of the rotating motor and the dumper returns to its normal position. On the return movement when the dumper is within about 10 deg. of its initial position, the clamping motor is cut out by a limit switch operated by one of the clamps. The rotating motor is also stopped on its return movement by a limit switch and the rails are held in correct alinement by a solenoid brake.

Without doubt the most outstanding feature of this car dumper is its fool-proof construction and its simplicity of operation. It is impossible for the operator to perform the cycle in any other but the correct way. The supporting of the car at the dumping side and the clamping at its top are both automatic and their operation depends solely upon the rotation of the dumper.

Another feature of this dumper is the placement of the counterweights. Extreme care was used in determining the amount and correct location for the counterweights used and the result has been the minimizing of the power requirements. The rotating motor is of 35 hp. but the entire structure is so well balanced that ammeter readings, which have been taken, indicate the size of motor furnished far in excess of the actual power required. The gondola car dumper was designed, manufactured and erected by the Link-Belt Co., of Chicago.

Comparison of Water and Steam-Power Costs*

SHOWING THE RELATION BETWEEN STEAM GENERATION AT THE LOAD CENTER AND WATER GENERATION AT A DISTANCE. BY GEO. A. ORROK[1]

DESIGN, construction, and operating results of large steam plants are well known and from examples which have already been constructed it is possible to predicate very accurately the cost figures which most probably would result under any given combination of circumstances.

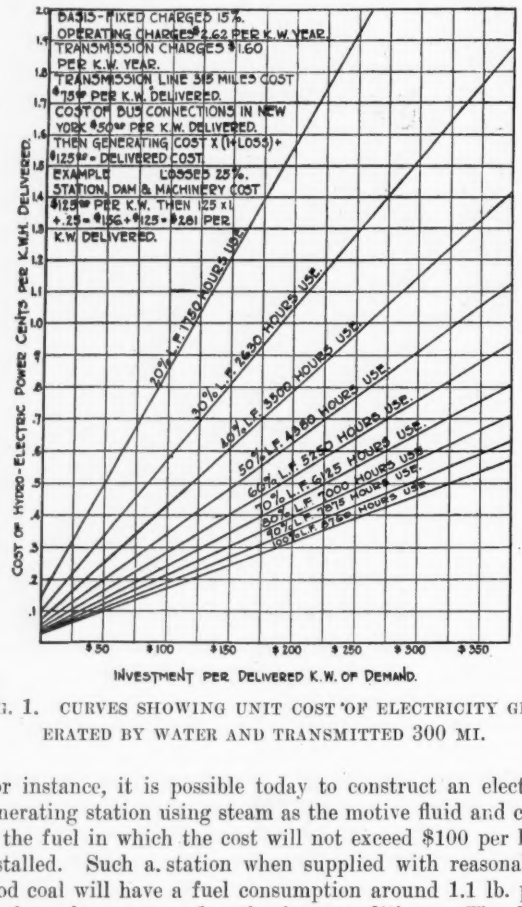

BASIS-FIXED CHARGES 15%.
OPERATING CHARGES $4.62 PER K.W. YEAR.
TRANSMISSION CHARGES $1.60 PER K.W. YEAR.
TRANSMISSION LINE 315 MILES COST $75 PER K.W. DELIVERED.
COST OF BUS CONNECTIONS IN NEW YORK $50 PER K.W. DELIVERED.
THEN GENERATING COST X (1+LOSS)+ $125 = DELIVERED COST.
EXAMPLE LOSSES 25%.
STATION, DAM & MACHINERY COST $125 PER K.W. THEN 125 x 1.25 = $156 + $125 = $281 PER K.W. DELIVERED.
20% L.F. 1750 HOURS USE.
30% L.F. 2630 HOURS USE.
40% L.F. 3500 HOURS USE.
50% L.F. 4380 HOURS USE.
60% L.F. 5250 HOURS USE.
70% L.F. 6125 HOURS USE.
80% L.F. 7000 HOURS USE.
90% L.F. 7875 HOURS USE.
100% L.F. 8760 HOURS USE.
COST OF HYDRO-ELECTRIC POWER CENTS PER K.W.H. DELIVERED.
$50 $100 $150 $200 $250 $300 $350
INVESTMENT PER DELIVERED K.W. OF DEMAND.

FIG. 1. CURVES SHOWING UNIT COST OF ELECTRICITY GENERATED BY WATER AND TRANSMITTED 300 MI.

For instance, it is possible today to construct an electric generating station using steam as the motive fluid and coal as the fuel in which the cost will not exceed $100 per kw. installed. Such a station when supplied with reasonably good coal will have a fuel consumption around 1.1 lb. per kw.-hr. when run under the best conditions. The law under which the coal consumption varies with the station load factor is well understood and labor and maintenance costs are known within reason. It may be assumed that fixed charges are 15 per cent. With coal running from $4 to $10 per long ton at the station, suitable curves can be drawn which will show the cost per unit delivered to the distribution system at any given load factor.

For the sake of comparison a steam station may be figured as having five 50,000-kw. units, allowing one as reserve and 200,000 kw. may be taken as the peak load on the station from which the load factor has been figured. It may be assumed that Pocahontas or equally good coal will be used and that the installation will be modern in all its details and located where there is an adequate supply of good condensing water.

HYDROELECTRIC PROBLEM BASED ON 300-MI. TRANSMISSION

With hydroelectric power, on the contrary, no such general statement can be made, and a separate and accurate estimate must be made for each and every condition. Sometime ago in the discussion of a problem of this kind a set of curves were developed, Fig. 1, which covered the cost per unit of electricity generated by water and transmitted over a 300-mile transmission line to the point of use, which in this instance was a large city. The transmission line was figured at $50,000 per mile, and the entire plant was proportioned on the basis of a demand on the peak of 200,000 kw. delivered at the point of use 300 miles away. reserve, four circuits, the necessary step-down apparatus and the high tension underground cables and other apparatus required to connect up this large amount of power to the distribution system of the city.

As the cost of the installation could only be known in a general way, these figures were made to cover a wide variety of total installation cost per net kilowatt of demand and the cost per unit was worked out for various load factors from 20 to 100 per cent, or from 1750 to 8760 hours of use per year. With these curves and the curves which were made for the steam station, Fig. 2, the price of which included its connection to the distributing system, it is possible to make a rather accurate comparison of the respective advantages of steam power and water power under the conditions stated.

*Presented before a joint hydroelectric session of the A. S. M. E., A. I. E. E. and the A. S. C. E., held during the annual meeting of the A. S. M. E.

[1] Consulting Engineer, N. Y. C.

It will be seen that for $4 coal and 100 per cent load factor, corresponding to an output of 1,750,000,000 kw. hr. per annum, the total costs of steam generated in the large center and water power generated 300 miles away and transmitted to the city are about even when the cost of the hydraulic generating station does not exceed $150 per kw. installed. This point with $6 coal is about equal to $200 per kw. of water installation, and with $8.50 coal to $250 per kw. of water installation. The curves for the steam station are a good deal flatter, however, than the curves for hydroelectric stations, and the various load factors at

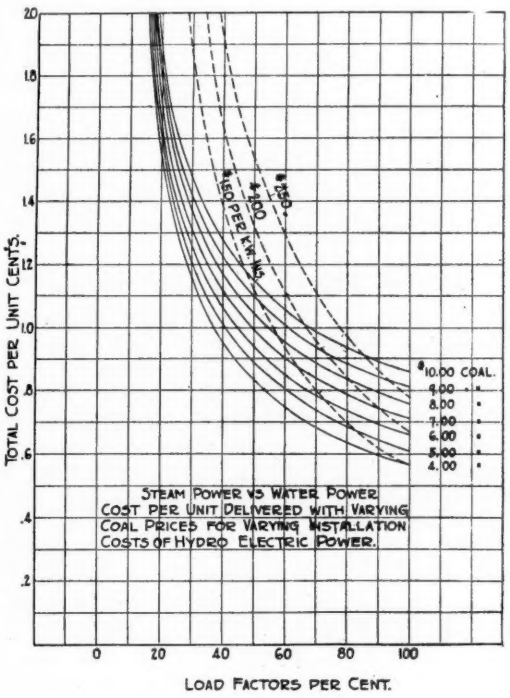


FIG. 2. STEAM POWER COSTS PER UNIT DELIVERED FOR VARYING HYDROELECTRIC INSTALLATION COSTS

which the hydroelectric becomes uneconomical can be readily seen from the diagram.

40 Per Cent Load Factor Is Low Limit for Use of Hydraulic Power

Using the water generation curves at $150 per kw. of installation, it will be noted that as the price of coal increases the load factors at which hydroelectric power becomes attractive decrease. With $5 coal this limit is 83 per cent, with $6 coal about 73 per cent, with $7 coal about 64 per cent, and with $8 coal about 58 per cent but it will be seen from the curves that about 40 per cent is the low limit for the use of hydraulic power, however high may be the coal price.

It is believed that in the calculations which have been made to construct these curves, a leaning has been indicated toward the hydroelectric side rather than to the steam side, and some of my friends have criticized me for using such a high figure for the cost of the steam generating stations. Criticism has also been made for not increasing the $50,000 used as the cost of a four-circuit, 250,000-volt transmission line but it is believed that the advantage has been given in this case to the hydroelectric installation.

Some years ago an investigation was made of more than three hundred water-power prospects in New York state. Considerable work was put into surveys and the estimates showed that the installation cost of these powers averaged $450 per kw. Only a very few ran under $200, and none under $150. It appeared from this investigation that coal must approach $10 to $12 a ton before even a small number of these projects would become commercial. But the larger powers of the St. Lawrence and Niagara may possibly figure in the range indicated in the curves and make up for the additional cost of long-distance transmission.

In prewar times, when coal seldom rose above $5 per ton, $125 per kw. of installation was considered as the limiting sum that could be spent on a hydroelectric installation, even where short transmission lines were involved. With the raising of the coal price as well as the cost of all construction work, this figure may perhaps be as high as $200 per kw. where the market is not far away.

Summing up, the curves show the relation between steam generation at the load center and water generation at a distance with coal prices within the range indicated. The transmission cost does not exceed 20 per cent of the total cost of water power and minor variations in distance or cost affect but little the location of the curves, nevertheless water power, even when more costly than steam power, has a place where coal is costly and may be impossible to obtain. The great extension of hydroelectric stations in certain European countries can only be justified by their lack of coal supplies.

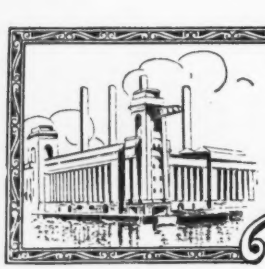
Reversed Generator

Not long ago, a young chap was employed to operate a power station which supplied current for an electric railroad. The equipment consisted of one d.c. generator in addition to other a. c. units. This d. c. unit was tied in with another similar unit at a plant about 4 mi. distant and a close watch had to be kept on the terminal voltage to prevent its dropping below the line potential, an event which would cause a current reversal and consequently a reversal of the generator field.

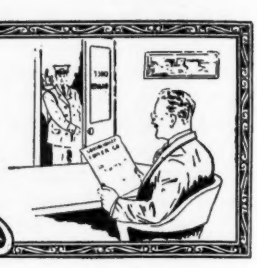
After the young man had been on the job a few days with the regular man, he was left alone with his duties. As things went along well for a while, he neglected to watch his generator voltage, with the result that there was trouble; the breaker on the line would not stay in. This, he supposed, was due to trouble on the line, so he called the load dispatcher and explained the situation. After several questions as to what was wrong and the nature and symptoms of the trouble, the dispatcher asked whether his generator wasn't reversed.

"Oh no," said the young man, "that is not the trouble, as the generator is still going in the same direction."

In view of the fact that large amounts of fuel oil and natural gas are used for fuel in oil refineries, a series of efficiency tests is being conducted by the Department of the Interior at the Petroleum Experiment Station of the Bureau of Mines, Bartlesville, Okla., to determine the relative efficiencies of various types of refining equipment. The results of these tests should aid in the development of refining equipment which will conserve a part of the natural gas and fuel oil now burned in oil refineries for fuel.

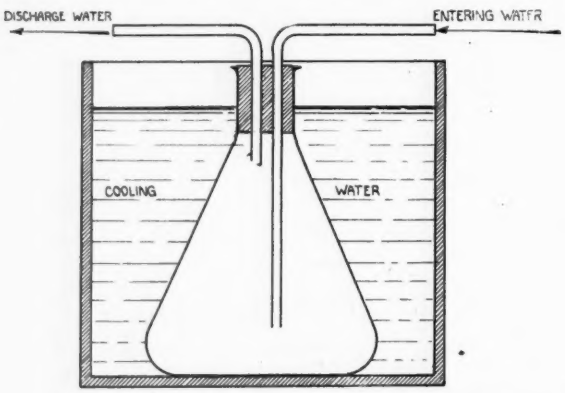


LETTERS DIRECT FROM THE PLANT



Correct Samples of Water to Analyze for Oxygen

In many of the larger plants, it is the practice to determine periodically the oxygen content of the feed water, such determinations being of great value in locating and stopping leaks at pump glands and other sources of oxygen contamination. In plants where the oxygen content of the



COOLED FLASK FOR CORRECT WATER SAMPLES

water is low, such as those using deaerators, great care must be taken in order to prevent the aeration of the water sample as it is taken.

If the temperature of the water being sampled is above the boiling point, some water will flash into steam which will carry away a great deal of the oxygen that was dissolved in the water. Again, if the temperature of the water sample is low, the sample is likely to dissolve oxygen from the air with which it is in contact.

The writer has tried several methods of taking samples in order to find one which prevents the flashing off of oxygen as well as absorption of oxygen from the air. It was found that a film of oil placed on top of the water would prevent contact with the air but this was objectionable because of the difficulty of washing the flasks after use. After considerable experimenting, the following method was adopted and has been found satisfactory.

As shown in the illustration a flask is fitted up and placed in a bath of water having a temperature considerably below the boiling point. The water is admitted through a glass tube which goes nearly to the bottom of the flask. Water is allowed to flow through the discharge tube for a time and then the flow is reduced until only a slight amount comes out. The discharge tube is then removed from the rubber stopper and the chemical solutions added with pipettes through the discharge hole in the stopper. The slight flow of the water through the discharge opening serves to prevent the aeration of the water used as a sample.

After the sample has been fixed, the flow can be stopped and the sample taken to a laboratory for titration. With water only a few degrees above the boiling point, no cooling other than that from the water surrounding the flask will be necessary. With very hot water, it will be desirable to run it slowly through a coil immersed in a bucket of cold water. When sampling cold water such as that taken from the discharge of condensate pumps, it will be unnecessary to surround the flask with water.

New Kensington, Pa. Harold Edwards.

Insulation of Furnace Walls

In the Dec. 15 issue of Power Plant Engineering, Mr. Frankenhoff reviews my comments of Aug. 1 on his article of June 15. He states that ". . . the temperature on the furnace wall is dependent to a great extent on the pressure conditions obtaining in the furnace. Mr. Sandstrom seems to have overlooked this important fact." He refers to an article by Joseph Harrington in the March 27, 1917 issue of Power describing temperature tests of insulated and uninsulated furnace walls.

In the article quoted two walls are shown, one of which is built of 9 in. firebrick exposed to the fire, backed by 4½ in. of insulating brick and this covered with 6 in. of concrete. The total thickness is 19½ in. The other wall is 25 in. of firebrick. Temperatures within the walls were taken with thermocouples. Just how the temperature of 2500 deg. for the inside faces of the walls was determined is not stated. The temperature gradient for the combination wall was 2500 to 1505 deg. through the 9 in. of firebrick; 1505 to 455 deg. through the 4½ in. of insulation, and 455 to 185 deg. through the 6 in. of concrete. The temperature gradient through the 25 in. firebrick wall was 2500 to 1470 deg. through the first 9 in., 1470 to 1070 deg. through the next 4½ in., 1070 to 675 deg. through the next 6 in., and 675 to 285 deg. through the remaining 5½ in.

The foregoing tests illustrate the importance of furnace conditions in making deductions from different kinds of construction. Also, because of the different construction of the two walls under discussion, a fair comparison cannot be made in this case. Forced draft was used. In the insulated wall the movement of the gases through the brickwork was checked by the outside covering of concrete which is impervious to low pressures. The firebrick wall not being so covered, permitted the hot gases to pass through, resulting in higher temperatures. Any one who has been through the experience of changing from natural to forced draft can testify to the change from comfort to discomfort of the boiler room, and the much higher temperature of the boiler setting. In the case of natural draft and the usual thickness of wall, the hand may be held on the brickwork with comfort; with a change to forced draft the wall can barely be touched. I believe that in two walls

of equal thickness, one solid firebrick and the other with a thickness of insulating brick, the latter will show higher temperatures through it when operating under forced draft. Under natural draft, the greater resistance to conductivity of the insulating brick wall will manifest itself.

In Bulletin No. 8 of the Bureau of Mines, a paper by Ray and Kreisinger, is a chart showing the temperature drop through a brick wall 19 in. thick with a 2-in. air space. At 1 in. from the inside face of the wall there was found a temperature of 1935 deg. F., and at 8 in. the temperature was 1039 deg. F. Between the 8-in. and the 12-in. points the air space manifested itself and the temperature drop was from 1039 to 742 deg. F. From the 12-in. point to the 18-in. point, 1 in. from the outside face of the wall, the temperature fell from 742 to 236 deg. F. The temperature gradient from 1 in. from the inside face was from 1935 to 236 deg. F. Had the wall been of solid brickwork, that is, without air space, the temperature drop would have been greater. Here is the work of noted investigators that differ greatly from results of tests quoted by Mr. Frankenhoff. The difference may be due to the personal equation; to unwarranted assumptions; to the different furnace conditions (natural or forced draft), or combinations of these.

I do not question the possibility of heating to redness an iron rod imbedded in a brick wall, this depends entirely on its distance from the heated face. What I said was that I did not believe that at 17 in. from the inside face of a brick wall enclosing a temperature of 2500 deg. there exists a temperature 100 deg. above red-heat. The chart used as a base for Mr. Frankenhoff's argument shows a temperature drop from 2500 to 500 deg. through a 22½ in. uninsulated brick wall. At a distance of 17 in. from the inside face of the wall the intersection of the temperature gradient indicates a temperature of about 1050 deg. F. I question this temperature.

Mr. Frankenhoff states that a temperature in excess of 2700 deg. is seldom exceeded in cement-kilns. As a matter of fact such a temperature is a minimum. Sound cement clinker cannot be produced at less than 2600 deg. and high-lime clinker requires a considerably higher temperature. Indeed, temperatures approaching 3000 deg. are the rule. When one considers the air for combustion entering the kiln at upwards of 800 deg. and oil, or pulverized coal as fuel, then it is not hard to believe that temperatures exist higher than those attained in boiler practice.

Many cement manufacturers line the firing zones of rotary-kilns with 9-in. firebrick blocks but the trend is toward the use of 6-in. blocks because at this thickness there seems to be an equilibrium between the mechanical and thermal resistance of the brick and the temperature drop caused by heat loss from the shell. The 6- or 8-in. layer of clinker that Mr. Frankenhoff states adheres to the brick and which offers protection is an undesirable feature and does not obtain in the combustion zone in good practice.

Mr. Frankenhoff states that "The elastic limit of steel does not depend on the temperature, by definition." About this there is no argument. What I said was, "A steel column at 1500 deg. several hundred degrees above the point at which the elastic limit is reached, would certainly be of no value as a structural member . . ." The elastic limit is the point where deformation ceases to be proportional to stress, and in the case of a column loaded when cold to one-half the elastic limit, an increase of temperature above 1000 deg. would wipe out the margin of safety and the column would fail.

Mr. Frankenhoff cites $45 to $50 as current cost of laying a thousand common brick and $115 to $125 as the cost of a thousand insulating brick. I have installed common brick in boiler settings at $37 a thousand. This cost can easily run to $50 when the bricklayer is put to work with nothing but his conscience to guide him. A little more than a year ago I received a quotation of $105 a thousand on insulating brick which, when laid, would run as high in cost as 3000 to 4000 common brick.

I have never had the opportunity to test the relative imperviousness to air infiltration of common brick and insulation brick but, having frequently analyzed gas samples from different passes of boiler settings that were apparently tight and, finding air infiltration that could hardly have passed through the joints only, I was forced to the conclusion that the brick itself was not impervious to air. If this be true for a common brick weighing 5 lb., what must be said for an insulating brick (reduced to the same size) weighing less than 2 lb.? When the total thickness of the wall is reduced on account of the use of insulating brick, then the air infiltration must be greatly increased. This condition, of course, does not obtain in settings under forced draft. In the latter case the loss would appear in the hot gases leaking outward through the walls.

Mr. Frankenhoff states that the conductivity of red brick is approximately eight times that of a high-grade insulating brick. The conductivity of a material is not an indication of its heat emissivity or overall heat transmission.

It was not my intention to doubt the existence of furnaces of the size stated in Mr. Frankenhoff's article of June 15. What I said was that there was ". . . error in assuming that any boiler has 1040 sq. ft. of furnace wall at *a temperature of 2500 deg.*

In my letter of Aug. 1, I described an I-beam column imbedded in a 22½-in. brick wall. One of the men who assisted in dismantling this setting assures me that the thickness of the wall was 27 in. up to the tube line where it was reduced to 22½ in.

Kansas City, Mo. C. O. SANDSTROM.

Deciding Factors in Choice of Combustion System

COMMENTING ON the article, "Factors in the choice of a Combuston System," by Edwin Ricketts which appeared in the Dec. 1 issue, I believe that a more detailed summarization of the factors given would facilitate the selection of a suitable system. Before going further, I would like to add another consideration, that of control of the furnace temperature.

Pulverized coal has an advantage over the stoker in this respect as the rate of firing with pulverized fuel may be instantly changed to meet varying load demands with the result that better economy in fuel is obtained.

Regarding the cost of labor, I believe that in the small plant equipped with the unit system of pulverized coal this item will not be more and will probably be less than with a stoker installation.

In summarizng these considerations, they can be seperated into two groups as follows:

Group 1 to include those factors which distinctly favor a particular type of combustion system regardless of the nature of the plant.

Group 2 to include those factors which may favor either system depending upon the nature of the plant or other conditions.

GROUP 1.

Three factors in favor of stokers.

1. Cost of plant (not including ash handling and disposal) is less.
2. Cost of auxiliary power (not including ash handling and disposal) is less.
3. Fire hazard is less.

Seven factors in favor of pulverized coal.

1. Better operating efficiency with coal of constant quality.
2. Less effect on capacity and efficiency of daily and hourly fluctuations in coal quality.
3. Reasonably good efficiency and capacity with all types of coal.
4. Less outages for repairs.
5. Stand by losses are less.
6. Better adapted to preheated air.
7. Better regulation.

GROUP 2.

1. Ash carried up the stack.—Not objectionable in some localities.
2. Ash handling and disposal.—Stoker ash can better be disposed of in some cases.
3. Cost of labor.—May be less with the unit system of pulverized coal than with stokers.
4. Cost of repairs.—Varies with type of equipment.

Bearing in mind then the increasing importance of high thermal efficiency, ability to handle poorer grades of coal and the tendency toward the use of preheated air, the relative value of the three items in favor of stokers may be balanced against the seven in favor of pulverized coal in Group 1.

The relative value of the four items in Group 2 will then qualify the result and be the deciding factor in the choice of a combustion system. S. MARTIN

Fuel Oil Burning Improved

TWO HEINE boilers, rated at 358 hp. each were fired with fuel oil using "Anthony" burners and air under pressure. It was difficult to get the air used right.

Operators would open the damper in the uptake wide, then raise the air shutters in the back a little, allowing air to feed in through the checker work, which extended to within about 4 ft. of the back wall. They would then speed up the fan which furnished the air to give a pressure of 8 to 10 oz.

Steam pressure was uneven; when it started to drop, it would fall until the load let up, the air fan, meantime, slowing down until the air pressure was only 4 to 6 oz.

On the open feed-water heater, the cold water supply valve, float-operated, was leaking so that the heater overflowed all the time, with the result that the pump was delivering cold water to the closed heater, and feed water came to the boiler at low temperature.

First the float valve was repaired, which resulted in getting water to the boilers at 225 deg. F. Then we cut down the air openings through the checker work and took out the air shutters at the back of the boilers. Dampers in the uptake were set at less than half open and the fan run so as to deliver air at as near 6 oz. pressure as possible, variation in load being taken care of by varying the position of the dampers. We try to run with just a light haze at the top of the stack.

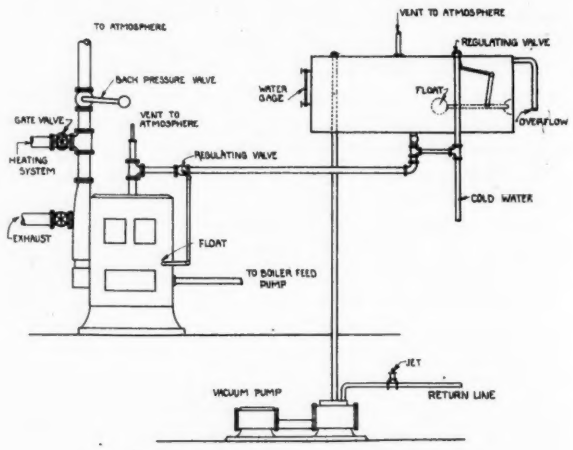
As a result, the oil burned has been cut down, steam pressure is steady and, with a large heating system going we can carry the load most of the time on the two boilers.

We find that the closer we watch the air going into the oil-burning furnace, the better economy we get. Oil pressure is 80 to 90 lb. at the burners but we can get a temperature of the oil of only 180 to 190 deg. which we feel is too low.

We would like to hear the experience of brother engineers using oil burners. M. W. C.

Making Changes in Heating System

IN A BUILDING in New York where a vacuum heating system was used, automatic valves were installed on the radiators and the returns were piped to the feed water heater. Much hot water was wasted, especially in the



SHOWING USE OF WATER STORAGE TANK

mornings when first starting up. More water came back in the returns than the feed-water heater could handle and the surplus had to be blown into the sewer. The water always came back hot and it was decided to save some of that heat. A storage tank was arranged as shown in the accompanying sketch and connections made to the feed water heater. The storage tank would hold nearly three times as much water as the heater and for a great part of the day, no make-up water was required. The water level in the heater was maintained by a regulating valve operated by a float in the heater. A float in the storage tank governed the flow of make-up water.

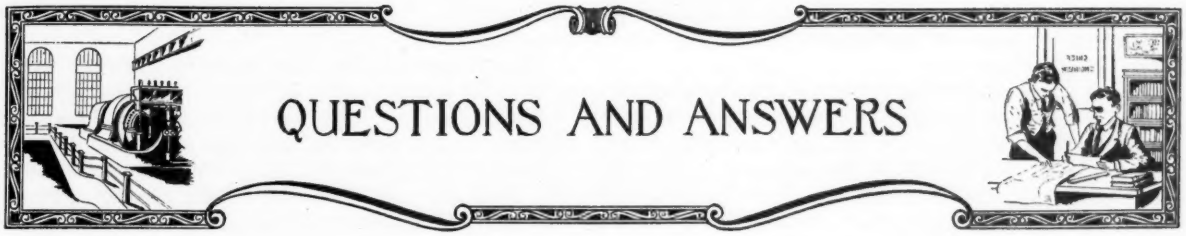
Utica, N. Y. M. M. BROWN.

A. C. Chain Grate Stoker Drive

I HAVE read with interest your description of the new Waukegan Station of the Public Service Company of Northern Illinois in the Jan. 15 issue but desire to correct an impression which you appear to have that a. c. motors for driving chain grate stokers were first used in this plant.

The Byllesby Engineering & Management Corporation has used a. c. motors for driving forced draft chain grates for the last two years and has used a. c. motors for stoker drives with underfeed stokers for the last 9 or 10 yr.

H. BOYD BRYDON.



QUESTIONS AND ANSWERS

Secondary Air to Complete Combustion

WOULD IT be possible to effect complete smokeless combustion of Kentucky coal containing 36 per cent volatile combustible matter by introducing cold air through the bridge wall from a point below the grate into the combustion space back of the bridge wall? It is expected that there will be a chilling effect resulting from this arrangement, but would the saving affected by more complete combustion offset this loss? H. C. R.

Refrigeration Plant Operation

WHEN I AM putting a charge of ammonia, say 100 lb., into a refrigeration system, after I have closed the valve in the liquid line from the condenser and pumped the system down to the point where the suction pressure is about 5 lb., do I have to open the expansion valve wider than usual while the new charge is entering the system?

2. How can I best tell when a refrigeration system requires a new charge?

3. What is the best method of pumping out an ammonia receiver so that repairs can be made on it?

J. B.

Are Traps Applicable Here?

I AM SENDING two sketches: Sketch No. 1 is the pipe line running from paper mill to boiler house and is nearly 800 ft. long. The paper mill is on one side of the river; sulphite mill and boiler house are on the other side. We are pumping the returns from engines, heaters and paper machines from the paper mill across the river to the boiler house.

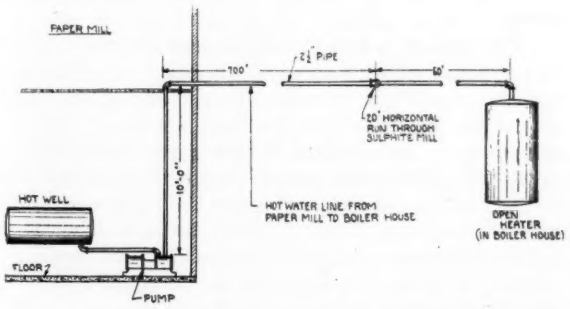


FIG. 1. PIPING ARRANGEMENT FOR RETURNS FROM PAPER MILL

It is necessary to cool the water off to 190 deg. F. so the pump will deliver it across to the heater in boiler house. What I want to do now is to put a trap on the paper mill side, to deliver the water across to boiler house just as hot as it leaves the machines. We use the exhaust from engines to dry the paper. What I want to know is what kind of a trap should I have on the paper mill side and I want another trap in the boiler house to pump direct to boilers. Would I have to put the trap in the boiler house above boilers or would it work if it was on the floor? From the top of the boilers to the floor is about 15 ft. We have Stirling boilers. About what power would it take to drive the water over to the boiler house from the paper mill? It is all 2½-in. pipe.

Returns from office, store house and hospital go to the paper mill sewer, as shown in Fig. 2. These pipes are under ground; from sewer in paper mill to ceiling is 9 ft. and from the hot well to the place where the returns from office go to the sewer is about 60 ft. Now, I want to get these returns to the hot well. We carry only 4 lb. on the heating system in the office and this will not force it to hot well. What kind of trap would force it to the hot well? I tried a trap on it but it would dump only once or twice and then refuse to work. What power will it take to force the water through 60 ft. of pipe and to lift it 9 ft. to the hot well from the sewer? W. J. M.

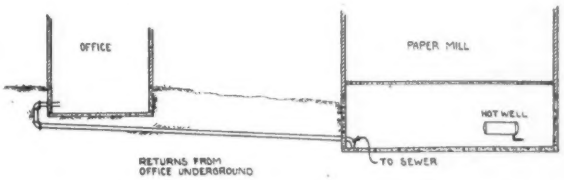


FIG. 2. RETURN PIPING FROM OFFICE BUILDING

Forced Draft Fan or Higher Stack

I WOULD like to have an opinion from Power Plant Engineering readers in regard to the use of a blower in a return tubular boiler setting. The grate is 5½ by 6 ft., having a surface of 33 sq. ft., and has very small air spaces. The unit carries a load and uses 5 T. of coal a day. Our present stack is 70 ft. high but it is in bad condition and the top 40 ft. must be taken down.

Would we be able to obtain better results by installing an undergrate blower to be used in conjunction with the 30-ft. stack than by building up the stack to 70 ft. and use it without a blower? If so, what capacity blower would be required? F. S.

Central Station Service vs. Isolated Plant

WE ARE at present considering the proposition of substituting central station service for the isolated power plant which we are now using and would like to have the opinion of Power Plant Engineering readers on the relative economies of the two systems. Would it be a paying proposition to discard the present Corliss type engine and install

motor drives? How would the economy of an oil or gas engine drive compare with either the steam engine system or central station service?

Normally from 3800 to 4000 lb. of coal per day is required for 9 hr. of operation. Exhaust steam at a pressure of from 3 to 5 lb. gage is utilized for heating the factory and office and also for heating the feed water to from 200 to 215 deg. F. Not long ago I had an opportunity to check up on the performance of the plant by weighing the coal used over a period of three days when the plant was not in operation, but during which time we carried the full heating load. We found that it required from 1600 to 2000 lb. of coal for a 9-hr. test per day. The variation was occasioned by weather changes from about 30 to 20 deg. F. The return water from the heating system as it came back to the heaters and boilers varied from 150 to 180 deg. F. We burn slack coal which costs us, delivered in the bin, close to $5 a ton. O. P. I.

Good Practice for CO_2 and Draft

How is CO_2 determined and what is its effect on combustion?

2. Is there any definite rule for draft above the grate to get the proper amount of air for combustion?

M. L. B.

ANSWERS

1. When coal is burned in air, the carbon particles unite with oxygen to form carbon dioxide or CO_2. Where the oxygen supply is limited, combustion in some parts of the furnace will not be complete and carbon monoxide, CO, will be formed. The volatile gases in the coal combine with oxygen and form either carbon monoxide, carbon dioxide or water vapor.

If CO_2 were the only gas formed during the process of combustion and if combustion were complete with only theoretical air requirements, the percentage of CO_2 in the flue gases would be the same as that of oxygen in the original air; that is approximately 21 per cent. In practice, however, it is not possible to burn the fuel as completely as this nor is it possible to cut down the air supply to the theoretical requirements, consequently the percentage of CO_2 in the flue gases is less than the percentage of oxygen in the air. In good practice, this figure is about 13 or 14 per cent, indicating about 30 or 40 per cent excess air. In general, it may be said that the higher the CO_2 percent, the more efficient will be the combustion up to the point where CO begins to be formed.

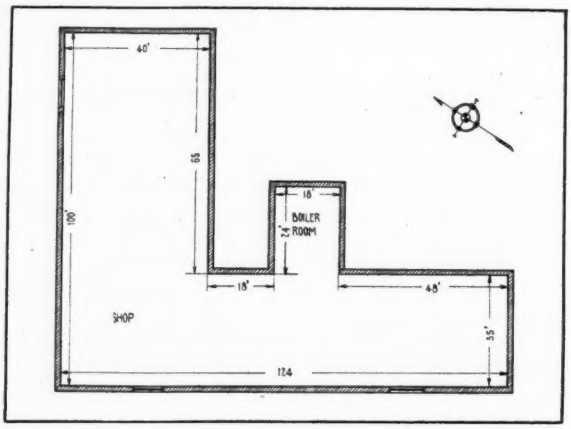
Determination of the amount of CO_2 in the flue gases may be made in a number of ways, the most common of which is by means of the Orsat apparatus. A representative sample of the flue gases is withdrawn from the uptake connection, and this sample is first measured volumetrically, then passed through a solution which dissolves out the CO_2. The reduction in the volume of the sample divided by the original volume will give the percent of CO_2 by volume. This same sample is then passed through another solution in which the CO is dissolved and the percentage of CO in the gases is measured by the ratio of the last decrease in volume to the original volume. CO_2 indicators are made which show the percent of CO_2 continuously as a direct reading on a chart.

There is no definite rule fixing the value of the draft over the grate in a furnace, but it is well to keep this draft as low as possible and it should also be as constant as conditions will permit.

In good practice this value varies from 0.05 to perhaps 0.25 in. of water. If it is greater than this amount, there will be a tendency for too much air leakage through the furnace setting above the grate line which results in decreased furnace efficiency. If a positive pressure is allowed for the grates, the furnace walls will become overheated and there will be a loss of efficiency from this condition.

Heating Requirements

To FIGURE L. B.'s factory heating surface as requested in the issue of Dec. 15, as a check on the plumber, he can probably use the figures given herewith. The problem is a little uncertain, as he does not give his location from which



LAYOUT OF BUILDING TO BE HEATED

it would be possible to figure on the outside temperature he would have to meet; but I have used zero deg. F., which is a fair average for central and middle Atlantic states.

The problem is first to find the heat radiated and then to proportion the coils and boiler to supply it. The radiation if figured from the constant representing heat transmitted per square foot of the wall, window or roof area per degree of temperature difference per hour; the temperature difference and area of each and an exposure factor, representing the effect of winds in increasing radiation and infiltration of cold air. This factor is usually taken as 1.4 on north walls and 1.2 on west walls. The inside temperature is assumed as 65 deg. F. for the shop.

Northwest wall—100 by 12 ft.—12 windows.

Glass area $12 \times 4 \times 6 = 288$ sq. ft.

Total wall area $12 \times 100 = 1200$ sq. ft.

Net wall area $1200 - 288 = 912$ sq. ft.

Radiation = exposure constant × radiation constant × temperature difference × area.

$1.4 \times 1.10 \times 65 \times 288 = 28{,}900$ B.t.u. per hr. (glass)

$1.4 \times 0.28 \times 65 \times 912 = 23{,}300$ B.t.u. per hr. (wall)

52,200 B.t.u. per hr. (total)

Southwest wall—124 by 12 ft.—15 windows.

Glass area $15 \times 4 \times 6 = 360$ sq. ft.

Total wall area $124 \times 12 = 1488$ sq. ft.

Net wall area $1488 - 360 = 1128$ sq. ft.

Radiation.

$1.2 \times 1.10 \times 65 \times 360 = 30{,}900$ B.t.u. per hr. (glass)
$1.2 \times 0.28 \times 65 \times 1128 = 24{,}600$ B.t.u. per hr. (wall)

55,500 B.t.u. per hr. (total)

Southeast walls—35 by 12 and 65 by 12 ft.—12 windows.

Glass area $12 \times 4 \times 6 = 288$ sq. ft.
Total wall area $12 \times (35 + 65) = 1200$ sq. ft.
Net wall area $1200 - 288 = 912$ sq. ft.

Radiation.

$1.00 \times 1.10 \times 65 \times 288 = 20{,}580$ B.t.u. per hr. (glass)
$1.00 \times 0.28 \times 65 \times 912 = 16{,}590$ B.t.u. per hr. (walls)

37,170 B.t.u. per hr. (total)

Northeast walls—$40 + 18 + 48$ by 12—11 windows.

Glass area $11 \times 4 \times 6 = 264$ sq. ft.
Wall area total $106 \times 12 = 1272$ sq. ft.
Net wall area $1272 - 264 = 1008$ sq. ft.

Radiation.

$1.00 \times 1.10 \times 65 \times 264 = 18{,}880$ B.t.u. per hr. (glass)
$1.00 \times 0.28 \times 65 \times 1008 = 18{,}350$ B.t.u. per hr. (walls)

37,230 B.t.u. per hr. (total)

No allowance is made for losses from the boiler room as it can be depended on to supply its own heat. Although there is no specific information given in regard to doors, but allowing for three 6 by 8-ft. doors having a western exposure the heat loss is

$1.2 \times 0.42 \times 65 \times 144 = 4730$ B.t.u. per hr.

Floor and roof.

Area, $(40 \times 100) + (35 \times 84) = 6940$ sq. ft.

Radiation.

Roof $0.30 \times 65 \times 6940 = 135{,}400$ B.t.u. per hr.
Floor $0.11 \times 65 \times 6940 = 49{,}600$ B.t.u. per hr.

Ventilation—two air changes per hour.

$6940 \times 12 \times 0.02 \times 65 \times 2 = 217{,}000$ B.t.u. per hr.

Then total radiation will then be the sum of these individual items or 588,830 B.t.u. per hr.

The process heaters have each a surface of about 4.8 sq. ft. and at 15-lb. steam pressure would radiate about 500 B.t.u. per sq. ft. per hr., or, $16 \times 4.8 \times 500 = 38{,}400$ B.t.u. per hr. Inasmuch as the process heaters will also be effective in heating the building, 38,400 may be subtracted from the building requirements leaving 550,430 B.t.u. per hr. to be supplied by the coils.

For factory work the coils should be supplied with boiler steam at 15 lb. as this will reduce the amount of coil surface required. For 1¼-in. pipe at this pressure the radiation will be about 550 B.t.u. per sq. ft. per hr. and the coil surface will have to be 1000 sq. ft. which is equivalent to 2300 lineal feet of pipe.

This should be distributed approximately in proportion to the radiating capacity of the walls.

..... three 28-ft. coils	Northwest wall	.....667 ft.
..... three 30-ft. coils	Southwest wall	.....713 ft.
..... one 20-ft. coil	Southeast wall	.....161 ft.
..... two 19-ft. coils	Southeast wall	.....299 ft.
..... one 23-ft. coil	Northeast wall	.....184 ft.
..... one 35-ft. coil	Northeast wall	.....276 ft.

Return head coils containing more than 100 to 120 ft. of 1¼-in. pipe are not satisfactory so that manifold coils would probably be more satisfactory. These could be proportioned about three along the longer sides two on the intermediate and one on the shorter, making all of equal height for the sake of apppearances. By a system of trial this would give 8-high coils. The arrangement indicated leaves sufficient empty wall space to allow for doors, windows and such items.

Using steam at 15 lb. little trouble would be experienced with circulation and 1-in. connections would be ample for each of the coils indicated, increasing the pipe area according to a table of equivalent areas as these are connected each toward the boiler. The coils should have individual traps and the returns should be carried to a receiver set low enough, in a pit, to give a good return grade to the pipes, the receiver being a float governing a pump which would pump the returns direct to the boiler.

The heating requirements alone amount to about 20 hp., but for process work and to take care of heating up in a reasonable time in the morning, at least a 30-hp. boiler should be installed. The usual size boiler for this capacity is 44 in. by 10 ft., with forty-two 3-in. tubes. A stack 18 in. diameter and 40 ft. high would suffice. In setting the boiler, better results will be obtained if it is set with the bottom of the shell 36 in. to 42 in. above the gate as higher capacity and less smoke will result than with a lower setting.

Unless oil were extremely cheap there would be nothing to gain by burning it instead of coal. This boiler would require only occasional firing and the coal and ash could easily be handled by someone whose regular work did not require constant attendance.

I have given the calculations in full so that L. B. can change them to suit his condition if the assumptions we have had to make are not correct. It should be remembered that there is quite a bit of leeway permissible in the operation of the system so that it is not necessary to figure to the last square foot.

New Haven, Conn. H. D. FISHER.

Capacity of Boiler Stack

AT PRESENT our stack is 110 ft. high, 48 in. diameter. We have two horizontal return-tubular boilers 16 ft. by 72 in. and want to add a 500-hp. boiler, leaving the two old ones for spares.

Will it give enough draft for the new boiler if we add 40 ft. to the height of the stack? W. C. F.

According to Kent's formula for the size of chimneys for boilers a stack, 150 ft. high by 48 in. in diameter would serve a commercial rating of 426 hp. based on a fuel consumption of 5 lb. per hp. hr. It is possible that you will want to operate your boilers at more than rating on occasion and it would seem best to use a larger chimney. It might be possible to add on another 25 ft. to your present stack (in addition to the 40 ft. you recommend) but this would result in rather a high chimney for a diameter of 48 in. A chimney better suited for your needs would be 54 in. in diameter by 150 ft. high.

Would the Installation of a Stoker Be Advisable?

WE HAVE in our plant three horizontal return-tubular boilers, one, 66 in. by 18 ft. and two, 60 in. by 16 ft., which are hand fired at the present time. We believe that they are taking too much coal and have been considering the possibilities of installing stokers.

Would they prove to be a profitable investment in this size of plant? If so, what type of apparatus would be best adapted for our needs? C. W.

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Federal Tax Reduction

Like many individuals, Congress has the tendency to spend all the money it can get hold of but at this time especially, when elections are approaching, it is likely to take account of the wishes of the voters. Everybody would like to see taxes reduced. Report of the Treasury Department for last year makes this seem possible, so the question becomes how best to do it. In all plans proposed, relief of the small tax payer is included. This is proper, but it is questionable whether release of a large number from all federal taxes is good from either an economic or a civic standpoint. Taxes should, so far as needs of the government permit, be laid so as not to be a burden. But, subject to that condition, there seems no logical reason why every person should not contribute something directly to the support of his government. The more raised in this way, the less will have to be raised indirectly and direct taxes are likely to be more equitably distributed than indirect. Also a voter who is paying a direct tax to support his government has always a liver interest in the actions of his representatives than one who thinks that government is costing him nothing.

Large incomes can and should pay a higher rate than small ones but the rush of capital to tax-free securities and to non-income-producing, long-time speculative investment has proved that too high a rate decreases rather than increases the returns. This is bad for industry, bad for government and bad for municipalities which are tempted to excessive expenditures by the ease with which their bonds can be marketed.

Generally, we credit those who have access to the best information and who have studied a subject most with being best able to advise on a course of action. This would indicate that the Treasury Department recommendations would naturally be the ones to follow and the sentiment of the country is apparently with them. It is possible that some changes in detail might result in a more equitable taxation, but it would seem the part of wisdom for everybody to agree with the general principles of a moderate payment by all except those whose incomes are near the line of making living ends meet and such tax on larger incomes and industrial concerns as will result in the maximum of industrial investment and activity, the reduction of issue of tax-free securities and the largest total return from the taxes on large incomes; then to let Congress know that the voters of the country want a tax bill passed which meets these conditions without regard to what the effect may be on the political careers of any individuals.

Increasing Profits from Steam

It is generally agreed that from one-sixth to one-fifth of the money spent for the generation of heat and power for America's industries is indifferently wasted. Not that knowledge for the improvement of this condition is lacking nor that manufacturers of power equipment can not supply equipment which, if intelligently operated, would greatly reduce this waste. It is purely a case of unbelievable indifference because of which otherwise responsible business men will disregard the economies to be had from the application of scientific combustion principles, proper maintenance of equipment and the installation of equipment which has proved its economic worth time and time again.

Too often managers and executives turn their backs upon waste of fuel, while at the same time spending relatively large sums finding and overcoming small manufacturing wastes which in the aggregate are less than the one big loss in the manufacture of power.

This problem will be more readily appreciated, if it is understood that the production of steam from the raw materials,—coal and water,—is as much a manufacturing process as is the production of iron from the raw materials, ore, coke and flux. The power plant manufactures heat and power which it sells to the other manufacturing departments whose profits will vary as the cost of heat and power varies. The manufacturer's power plant holds a unique place in that it is the sole source of heat and power for his other departments and the market price of the commodities manufactured, as affected by power cost, is under the control of the manufacturer. He is overlooking a good business proposition if he fails to take advantage of the situation by installing modern equipment and insisting upon its proper maintenance and operation in order that he may reduce his cost.

Painting Interiors of Power Plants

One feature of power plant design that has been given little or no attention is the question of proper painting of walls, ceilings and mechanical equipment. No matter how carefully designed a lighting system may be as to type, size of lamps, reflectors, etc., if the surroundings are not adapted to reflect such light as strikes them, the effect of the lighting system will be lost.

Now, it is not only true that little attention has been given to proper painting in power plants, but the lighting systems themselves as a rule are hopelessly inadequate. The combined effect of these two conditions has made many an otherwise fine plant, a place of gloom and darkness.

Ceiling and wall surfaces in a room are secondary sources of illumination—receiving and reflecting light from lamps—and in many cases merely increasing the reflection coefficient of the ceiling a slight amount, will greatly increase the effective illumination. It is important therefore to paint the ceilings as light a color as possible.

In basements and on condenser floors particularly, every effort should be made to obtain high coefficients of reflection from all surfaces. This applies not only to the walls and ceilings but also to the equipment itself. This of course, does not mean that the coal handling equipment should be painted white or even the boiler feed pumps, but it does mean that such equipment can be painted some color other than black or dark brown.

Such equipment painted a medium green or a light gray will not only present a better appearance but will reflect the light and diffuse it in all directions, making all parts clearly visible. It is an easy matter to light mechanical equipment if the component parts assist rather than repel the light.

There is absolutely no reason why all machinery should be painted black as is the case in many plants. Black absorbs all of the incident light and produces extremely low visibility. One frequently visits industrial plants where in the factory buildings everything is light and airy, yet a visit to the power plant reveals pump rooms, condenser floors, and even engine rooms which are little better than dungeons, so far as brightness is concerned.

A bright plant is a cheerful and pleasant place in which to work and there is a natural tendency to keep light colored objects clean. A clean, bright, work place has a decided effect in improving the morale of the employes. It is human nature to neglect apparatus which is installed in places where it can scarcely be seen because of the gloom which prevails. There is no incentive on the attendants part to keep such equipment clean and furthermore, if something goes wrong he does not always detect it until the trouble has become so serious as to result in actual breakage and shutdown.

Place a machine in a light colored room, paint it a light color and there will be little danger of trouble existing for any length of time without being noticed. The attendant will unconsciously keep such a machine clean without apparent effort on his part.

It is agreed, of course, that a coat of paint will materially lengthen the life of most equipment, at least it will preserve it in better condition during its life. If that is the case, then why not put the paint to double use by using light colors? White, no doubt, would be preferred in any case, considered from the reflective standpoint, but this is not always feasible. Various shades of gray on the other hand, can be applied to almost any type of equipment with excellent results.

It is true that light colored surfaces will require more frequent cleaning and that this will add somewhat to the cost of maintenance. This increased cost due to cleaning, however, will be met by lower lighting bills, decreased repair costs, a smaller labor turnover and fewer accidents. The psychological effect of gloomy interiors is well recognized and it is desirable in all cases to keep the employes in a cheerful frame of mind. This will have a direct effect in reducing the labor turnover.

This question of proper painting of interiors has been given considerable attention by various industries and as a result of a campaign of education on the part of certain paint manufacturers, the industries now realize that natural light is greatly aided if the interior surfaces are light in color. The power plant is no different from the factory as a whole in this respect, and the results attainable are equally as important.

Engineers will do well to look into this question with a view to improving conditions in their plants.

Complete Mail Addresses

Uncle Sam, according to the Postmaster General, has to spend some $2,000,000 a year to complete the addresses of mail sent to the larger cities on which street and number are not given or are incorrect. Even in the smaller cities, wherever carrier delivery is made, a distributing clerk may not know the address of a business concern, so cannot tell to which carrier the mail should go. He must send it to the searching department which may be able to give the address quickly but, even so, a delay of 10 to 24 hr. in delivery of the mail will often result.

For their own interests, all manufacturers should furnish in advertisements, on circulars and on letter heads complete delivery address and should always be addressed in as full detail as possible. Care in these matters will facilitate doing business and relieve the post office of an unnecessary burden.

FUEL OIL is generally purchased on the basis of its volume at 60 deg. F. Should it be delivered at any other temperature it will be necessary to make an adjustment by using the coefficient of expansion. For California oils this may be taken as 0.0004 per deg. F.

POWER PLANT ENGINEERING DEVELOPMENTS AND NEWS

C E C Air Heater Employs Counterflow Principle

SEVERAL NOVEL features of construction are incorporated in the new air pre-heater recently placed on the market by the Combustion Engineering Corporation of New York City. This heater, known as the C. E. C. Air Heater is of the plate type and consists of a steel casing in which are contained a number of steel plate elements space 1 in. apart. The flue gas which serves as the heating medium, and the air to be heated, are divided into parallel streams which flow in opposite directions to each other; that is, assuming that the gas passes from the lower to the upper part of the heater, then the air will be drawn in at the top and taken out at the bottom. Obviously, the steel plates are hottest at the point where the flue gases enter and as the gases pass along there is a decreasing amount of heat available for absorption.

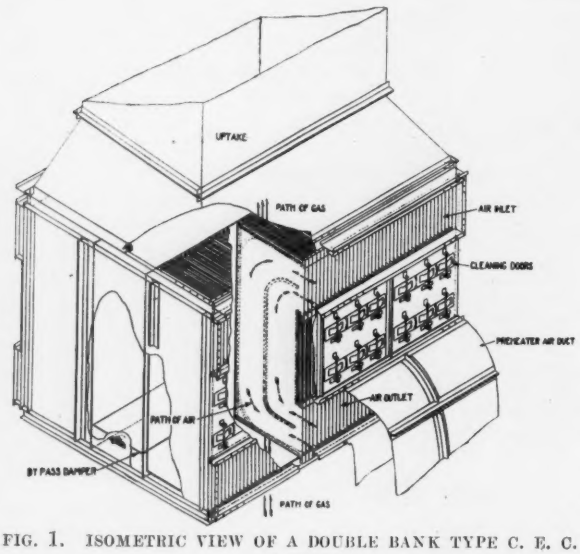


FIG. 1. ISOMETRIC VIEW OF A DOUBLE BANK TYPE C. E. C. HEATER

As a result of this counter-flow principle, the air, entering at the point from which the gases leave, encounters an increasing temperature as it progresses through the heater and consequently absorbs the maximum amount of heat. The temperature difference between gas is brought into immediate contact with the constant ratio.

Inasmuch as these parallel streams of gas which pass over the air elements are only 1¼ in. in depth, it is evident that practically all the gas is brought into immediate contact with the surface of the elements. This condition is also true of the air which is divided into parallel streams 1 in. in depth. Because of the fact that the streams of gas and air alternate, both plates of the element are brought into contact with the hot gas. This complete contact of both gas and air with the same heating surfaces results in a most effective transfer of heat. By eliminating the natural tendency of the gas and air to stratify, the heat transfer is uniform throughout the surface of each element.

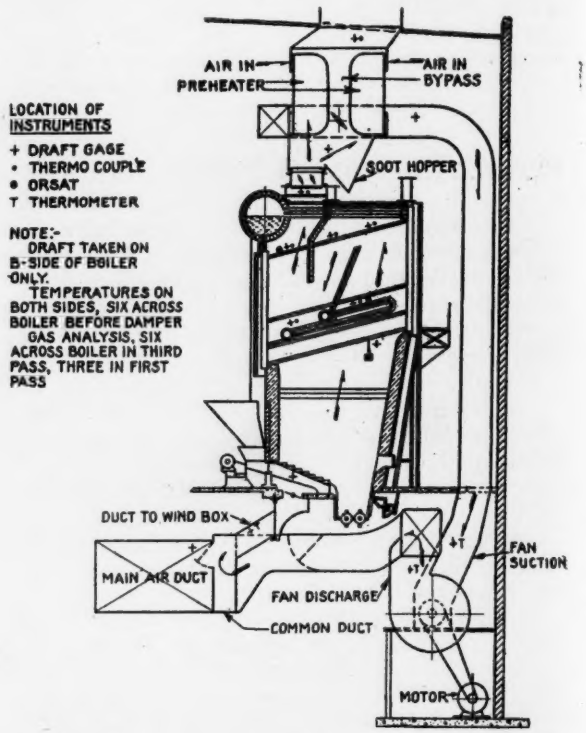

AIR IN PREHEATER
AIR IN BYPASS
LOCATION OF INSTRUMENTS
+ DRAFT GAGE
• THERMO COUPLE
• ORSAT
T THERMOMETER
NOTE:- DRAFT TAKEN ON B-SIDE OF BOILER ONLY. TEMPERATURES ON BOTH SIDES, SIX ACROSS BOILER BEFORE DAMPER GAS ANALYSIS, SIX ACROSS BOILER IN THIRD PASS, THREE IN FIRST PASS
SOOT HOPPER
DUCT TO WIND BOX
MAIN AIR DUCT
FAN DISCHARGE
COMMON DUCT
FAN SUCTION
MOTOR

FIG. 2. GENERAL ARRANGEMENT OF EQUIPMENT SHOWING LOCATION OF AIR HEATER

Within the air elements, the spacing is obtained by the use of several 1-in. angles which are suitably secured to one of the plates and act as both spacers and baffles. These angles are so located as to distribute the air over the surface of the plate and to prevent any tendency toward short-circuiting through the portion of the element where the length of travel is shortest. To the outside of each element are affixed a number of 1¼-in. angles which act as spacers for the gas passages between elements. The two plates which make up an element are secured together in such a way as to make a gas and air-tight envelope. This prevents air leakage into the gas passage which would lower the efficiency of the heater.

In the making up of a complete heater, the required number of elements are assembled side by side and enclosed in a steel-plate casing suitably braced throughout and pro-

vided with flange connection on the inlet and exit gas and air openings for connection to the air ducts and flues.

One of the prime requisites of any type of air preheater is that the heating surfaces be kept free from accumulations of soot. In the C E C heater, it is claimed, the slight weaving action of the plates will tend to prevent soot accumulations, and will assist the gases to carry away particles of soot, as they pass over the elements. Occasionally, however, it may be necessary to brush the gas passages with a steel brush, or blow them out with a steam lance.

Test results indicate that the draft loss in the heater is small. For this reason it is unnecessary to provide any great amount of draft as long as the quantity of gas which it is required to handle is kept within reasonable limits. With a gas rate of about 6000 lb. per sq. ft. of cross-sectional area, per hour, the draft loss will not exceed 0.5 in. The draft loss, of course, is affected to some extent by the manner in which the heater is heated. If the gases are permitted to pass through the heater vertically, it is obvious that the draft loss will be less than if they pass through horizontally.

A detailed account of a series of tests on this heater appeared on p. 1228 of the December 15th issue of Power Plant Engineering.

On the air side, the pressure drop is somewhat higher than that through the gas side, due to the increased density of the air and to the smaller cross-sectional area provided. In most installations the air is drawn through the heater by the suction of a fan which in turn is used to force it into the furnace.

As is true of any air preheater installation, the saving which may be effected increases in proportion to the amount of heat available in the escaping flue gases. Thirty per cent of the escaping heat may be economically recovered with this heater.

This type of heater has been manufactured in Europe by the Underfeed Stoker Co., Ltd., and they have made installations which have been operating satisfactorily for several years. It is therefore not an experiment or an untried proposition.

James Hartness Elected President A. E. C.

James Hartness, former governor of Vermont, and past president of the American Society of Mechanical Engineers, was elected president of the American Engineering Council to succeed Dean Mortimer E. Cooley of the University of Michigan, at the annual meeting of the Council, which was held in Washington, January 10 and 11. Addressing the Council, President Hartness declared that his administration would be characterized by effort aiming to aid, through the engineering profession, the American people in making the best use of the nation's energies and resources.

Vice-presidents elected were L. P. Alford, of New York and Charles R. Gow, of Boston. Other vice-presidents are Calvert Townley of New York and Gardner S. Williams, of Ann Arbor, Mich. Dr. H. E. Howe, of Washington was re-elected treasurer, and L. W. Wallace, of Washington was again chosen executive secretary.

An outstanding feature of the Washington assembly was the national Public Works Conference held on January 9, and attended by representatives of 63 engineering and allied organizations. The Conference adopted resolutions favoring a reorganization of Federal departments.

It was voted to set in motion again the nationwide movement for the establishment of a Department of Public Works, which, it was said, would save millions annually to the government and promote efficiency and stability in the conduct of Federal affairs. The movement will be directed by the American Engineering Council from its national headquarters in Washington. In association with the Engineering Council, an advisory council composed of one representative from each participating organization will function.

Philip N. Moore, of St. Louis, former chairman of the War Minerals Relief Commission, and one of the original sponsors of the public works project, was chairman of the Conference, which was addressed by Secretary Hoover of the Department of Commerce.

Secretary Hoover said he thought that no isolated bills for government reorganization could go through Congress and that the problem of regrouping public works functions was tied inseparably with the larger problem of general reorganization. Segregation of the vast public works functions, in his opinion, must be accompanied by parallel segregation of other activities.

A. C. S. to Hold Symposium on Heat Transfer at Spring Meeting

One of the features of the coming Spring Meeting of the American Chemical Society, which is to be held in Washington, D. C., during the last week in April, will be a Symposium on Heat Transfer. This will take place at the Central High School and will consume two sessions, probably Tuesday afternoon and Wednesday morning, April 22 and 23. It will be conducted by the Division of Industrial and Engineering Chemistry, and Professor W. H. McAdams of the Massachusetts Institute of Technology will be chairman. Following is a classification of subjects to be covered:

1. Heat Losses by Radiation plus Convection, through Bare and Insulated Surfaces.
   a. From Pipes.
   b. From Furnace Walls.
   c. From Miscellaneous Shapes.
2. Heating or Cooling of Non-Condensable Gases.
   a. The Warming of Air in Hot-blast Heaters.
3. Heating or Cooling of Liquids Flowing inside Pipes.
   a. Water.
   b. Oils.
4. Condensation.
   a. In surface Condensers and Water Heaters.
5. Evaporation.
   a. The Analysis of Certain Comparative Tests on Evaporators.
   b. Heat Transfer in Enameled Apparatus.
6. Miscellaneous Topics.
   a. "A Heat Meter."
   b. The Determination of Air in Steam, and the Importance of this Factor in Heat Transmission.

Plans for a new power plant for the Draper Corporation of Hopedale, Mass., are being prepared by John A. Stevens, consulting engineer, Lowell, Mass. It is expected that the construction of the plant will commence early in the spring.

Combustion Problem Discussed at Power Meeting

LIVELY INTEREST SHOWN IN POWER GENERATION AT FIRST ANNUAL POWER MEETING OF CHICAGO SECTION OF THE A. S. M. E.

MANY engineers prominent in the field of power generation were in attendance at the first annual power meeting held by the Chicago Section of the American Society of Mechanical Engineers. The entire day, Jan. 15, was devoted to the presentation of papers and discussion of problems encountered in the operation of power plants. At the dinner meeting in the evening, Fred R. Low, president of the A. S. M. E., gave an address on the activities of the society and its needs.

Paul W. Thompson, of the Detroit Edison Co., in an address on "The Central Station Power Plant," discussed the problems presented and recent developments in the field. He spoke of the growing use of mechanical stokers and their development to meet the requirements of both large and small boilers and all grades of fuel. Many different methods of cooling refractories have been employed, such as ventilated walls, the use of radiant type superheaters and water front bridgewalls which have lengthened the life furnace walls.

Air preheaters, it would appear from tests, can be used to increase the efficiency 5 per cent but the upper limit of the temperature at which preheated air can be used with stokers has not been determined. As to high pressure steam, he considered temperature the limiting factor and stated that materials used in turbine construction at the present time reach their critical temperature at a little above 750 deg. F. but that investigations are being carried on at the present time with other materials which may increase the temperature limit.

With steam at pressures above 500 lb., two turbines are required and the exhaust from the high pressure unit must be reheated before entering the low pressure turbine. This is done in order to reduce the amount of condensation in the lower stages which would otherwise become excessive and reduce the efficiency of the turbine. For highest efficiency with motor driven auxiliaries, steam must be bled from the turbine for heating the feed water.

Any plant that can deliver a kilowatt-hour with 20,000 B.t.u. in the fuel, he considers very well operated, though in rare cases the heat consumption has been reduced to 16,000 B.t.u. and it is possible to design a plant calculated to give an economy of 14,000 B.t.u. per kw.-hr. A binary vapor plant design can be worked out to show a possible heat consumption of 10,000 or 11,000 B.t.u. per kw.-hr. In his opinion, the combined gas and steam engine such as is installed in the Ford plant is probably an advance from present practice so far as efficiency is concerned but complications in design and cost considerations will probably limit its extensive use.

George C. Daniels, of Peoria, stated, in discussing the paper, that his company has been experimenting with steam at 300 to 400 lb. pressure. One of the difficulties encountered is refractory trouble which is cut down by lining furnace with a radiant type superheater.

Alex D. Bailey, of the Commonwealth Edison Co., Chicago, emphasized the importance of continuity of service and considered the complications necessary to secure highest efficiency lacking in complete reliability. To install a 30,000-kw. plant costs $3,000,000 which is too high an investment to risk in experimenting with unproven methods. Greatest efforts should be made toward reducing fuel costs as these, he states, constitute about 80 per cent of the cost of power.

That equipment now going into well designed central stations for the first time will prove reliable when operating details have been worked out, was the thought of John Anderson, of the Milwaukee Railway & Light Co. He cited the radiant type superheat as an example of equipment the reliability of which was greatly questioned a short time ago but which has proved to be of great advantage in his furnaces for burning powdered coal.

In his paper entitled "Power Generation in the Steel Mill," G. R. McDermott, of the Illinois Steel Co., described modern methods of utilizing heat commonly wasted in steel mills. Fire tube boilers used for absorbing heat from waste gases are designed for gas velocities up to the critical point, 1½ in. flues being used. Of the heat absorbed by these boilers 80 to 90 per cent is by convection.

Professor George F. Gebhardt, of Armour Institute, spoke of the opportunities to utilize heat rejected in power generation and industrial processes stating that if the exhaust steam can be used the isolated plant can show higher economy than the central station. With Diesel engines an efficiency of 72 per cent can be secured when the waste heat is properly utilized.

CONDITIONS AFFECTING TRANSFER OF HEAT

"Heat Transfer Through Turbulent Gas Flow" was the subject of a paper by Lloyd R. Stowe, of the LaClede-Christy Clay Products Co. He made the statement that the shorter the length of time that the gas is under the cooling influence of an economizer, the greater will be the amount of heat given off.

If we are to shape a definite amount of gas-cooling surface into an economizer and desire to employ some definite average gas velocity, this velocity will fix the total cross-sectional area of gas flow. It is readily apparent that if we then decide to use extremely small unit gas streams it will be necessary to use a great number of them.

Next, we will discover that per foot of length it takes more heating surface to bound a large number of small streams than is required to surround a smaller number of large streams having the same total area.

Considering a total cross-sectional area of gas flow then, considerably more surface is encountered per foot of gas travel with the small streams than is encountered with the larger ones and, since we are considering the use of some definite amount of heating surface, it is evident that the total feet of flame travel through the apparatus will be much shorter with the small streams than with the large ones. And since we are considering the same velocities in both instances, it is apparent that due to the shorter flame travel, a particle of gas will remain under the cooling influence of the boiler or economizer a shorter length of time when small unit gas streams are used.

If we could in some way induce an infinite turbulence in the gas flow—establish an absolutely perfect equalization of heat and temperature for each cross section, the heat transfer problem would be removed from a consideration of conditions of gas flow and be transferred to a consideration of conductivity of the metal and conditions on the water side of the metal. With infinite turbulence of

gas flow and equal conditions of conductivity and equally favorable conditions on the water side of the plate, 10,000 sq. ft. of economizer surface would have some definite and maximum efficiency regardless of whether streams were large or small, and in fact, regardless of how the surfaces were arranged. The efficiency would depend upon the ability of the metal to dispatch the heat from its gas side to the water.

The material part of this paper was the development of two simple yet extremely comprehensive rules—

1. Arrange that all the gas flows close to the tubes, through the use of small gas streams.

2. Use the minimum number of such streams.

The author concludes that:

1. As much heat as possible should be absorbed by radiation to the tubes about the fire where no expenditure of draft power is required, so that this draft power may be conserved to be employed later to abstract the heat from the gas through contact at a time when no other means are available.

2. Excellent combustion conditions involving long flame travel and the reduction of the temperature of fly ash below the fusing point in the "radiation" bank should be in evidence that the tubes may be brought closer together without courting cleaning difficulties.

3. With clean gas and no cleaning difficulties an ideal heat exchanger would be somewhat like the automobile radiator—a next to infinite number of very small streams and short gas travel, and incidentally with an extreme reduction in the time element

4. Since under the less ideal conditions with which we must content ourselves, and under which our chief concern is with the gas flow, the diameter of water tubes is of no particular significance so far as heat transfer is concerned.

5. Having once reached the limit of small gas streams, any further increase in the effectiveness of surface is purchased at a price of increased power required to drive the gases through the boiler.

Underfeed Stokers Used with Western Coals

In his paper on underfeed stokers and their use with Middle West coal, Joseph G. Worker, of the American Engineering Co., stated that of the 1,000,000 boiler hp. installed during 1922, 800,000 were served by mechanical stokers of which 550,000 hp. were of the underfeed type. Although the underfeed stoker has been used most extensively in the East where coal has an ash that fuses at a high temperature, he contended that it is being used successfully with coals from the Middle West. The use of clinker grinders has made the furnace completely automatic in operation and the introduction of air through perforated side plates has prevented clinker from attaching to the side walls of the furnace walls.

R. N. Robertson, of the American Smelting & Refining Co., Omaha, stated that he is burning the worst coal in the district on underfeed stokers. While clinkers do form they do not seriously interfere with the operation. The greatest problem is so to design and operate the furnace that clinkers do not solidify and adhere to the side walls and that the refractory does not deteriorate.

Discussion also brought out that Colorado lignite is burned on underfeed stokers but the forced draft pressure must be kept below 2-in. of water to prevent the ash from being carried away with the gases.

Furnace Requirements for Pulverized Coal

In his address on "Pulverized Coal," Henry Kreisinger, of the Combustion Engineering Corp., pointed out that the most important part of a boiler plant for burning pulverized coal is the furnace and laid down five objects to be obtained in the design of the furnace. 1. Burn coal completely with little excess of air. 2. Furnace must stand high temperature and slagging action of ash. 3. Furnace must be so designed that ash can be removed easily while the boiler is in operation. 4. The fuel must be easily lighted and brought rapidly to rating. 5. The equipment must be safe in operation.

Sufficient combustion space must be provided and the size recommended is 1 cu. ft. per 25,000 to 30,000 B.t.u. generated from the coal per hour. The large furnace is essential to keep down repair costs on refractory materials and also to ensure proper mixing. While volume is necessary it is also necessary to have sufficient gas travel from the burner to the heating surface; 40 to 65 ft. gas travel is recommended.

With larger combustion space it is possible to use larger coal particles, 65 per cent through 100 mesh screen can be used when the combustion space is sufficient. This is quite an advantage as it increases the capacity of the pulverizing mill to about double what it can do in present practice.

Pulverized coal furnaces are much larger than we have been accustomed to; this is partly due to the fact that the flame must not strike the wall. Hot ash in a flowing state will dissolve the binder in the refractory and deteriorate the furnace lining, though if in a plastic state the coating of ash will protect the lining. The furnace is therefore constructed with hollow walls in which horizontal air ducts are formed by tile 18 in. long anchored to the outer wall, the inner shell being 9-in. thick, then an air space of 9 in. and an outer shell of insulation 5 in. thick. Air is drawn into the furnace through these ducts, thus heating the air and cooling the wall. About 75 per cent of the air required for complete combustion or 7 lb. air per lb. coal fired is supplied to the furnace in this way.

At the bottom of the furnace is a water screen to cool the ash. The tubes in this screen are placed on 10½ to 14 in. centers and the boiler water circulates through them. The evaporation in the tubes is equivalent to 1.5 hp. per sq. ft. of surface.

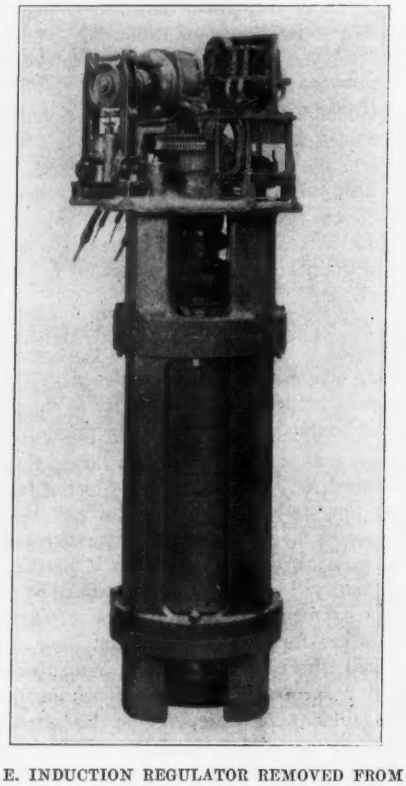
Nozzles for burning pulverized coal are somewhat the form of a fish tail gas burner ¾ in. thick by 15 in. wide; 1½ to 2 lb. of air per pound of coal is discharged with the coal through the jet and about the same amount around the jet. This constitutes 30 to 40 per cent of the air requirements. More air than this is likely to blow out the flame, especially if cold. A torch is used for lighting the first burner and this lights the others as they are turned on so that eight burners can be lit in 1 min. At the Springdale power station recently with the boiler on the line but a cold furnace the fire was lighted and the boiler brought up to 300 per cent rating in 4 min.

J. Van Brunt, of the Combustion Engineering Corp., gave a historical account of the forced draft chain grate stoker calling attention to the principles of ignition and zone control of combustion employed.

In his paper on "Burning of Waste Coal in Pulverized Form under Boilers," Ralph Galt, of the Fuller Engineering Co., told of the results obtained by a number of companies in burning coal mine waste and river coal and showed illustrations of the furnaces used.

New General Electric Voltage Regulator

SEVERAL DESIRABLE features are emphasized in the design of a new single phase induction voltage regulator which has recently been developed by the General Electric Co. of Schenectady, N. Y. Among these features,



NEW G. E. INDUCTION REGULATOR REMOVED FROM TANK

is a tank which is highly resistant to rupture; a mechanical structure of increased rigidity; coils with improved bracing to prevent insulation troubles due to short circuits; greater accessibility of operating mechanism, and improved voltage regulation due to the more rapid correcting of voltage changes.

A view of this regulator with the tank removed is shown in the accompanying illustration. The tank is of all welded steel design and is constructed of heavy boiler plate with heavy flattened steel boiler tubes for radiation. It is round with a view of obtaining maximum strength and freedom from distortion. This tank is an extremely efficient radiator of heat. Advantage has been taken of this characteristic to reduce the height of the regulator, resulting in a more rigid mechanical structure and increasing the accessibility of the operating mechanism. While the height of the regulator has been greatly decreased, the floor space is practically the same as in the superseded cast iron tank type.

For inspection purposes the regulator may be removed from the tank. The spider is of very heavy construction and the bearings at the top and bottom are located close to the windings. The core itself is built in a heavy spider section and securely clamped between heavy steel flanges. The top and bottom sections of the spider are likewise of heavy construction and all parts are accurately machined to insure perfect alinement. The short rigid spider construction insures quiet operation of the regulator over extended periods of time.

Shaft bearings in the cover and bottom are bushed with a high duty bronze and these bushings are provided with oil grooves to facilitate lubrication. The windings are provided with a high grade of insulation, so designed that the same factor of safety against failure between turns and layers is obtained as to ground.

Coil extensions beyond the core are short and the ends of the coils on both primary and secondary are securely reinforced to prevent distortion and failure of the windings from line short circuits. The motor is assembled at the back of the regulator with its brake on the left side and the handwheel for hand operation on the right. The relay and limit switches are assembled at the front of the regulator. The motor, brake, relay switch and limit switch are completely wired and all outgoing connections are brought to a terminal board just below the relay switch. With this arrangement of auxiliaries and due to the fact that the high tension leads are brought out at the back of the regulator, it is possible for the operator to make any necessary adjustments with ease and without danger of coming in contact with the high tension leads.

The motor used has a cast aluminum rotor winding. This allows an increase in speed from 900 to 1200 r. p. m., resulting in a reduction from 11 to 8 sec. in the time of operation from limit to limit of the regulator. Rapid acceleration and sudden stopping are also important features which have been included in this design. In connection with this motor, the magnetic brake used on these regulators is a comparatively recent development. It is noiseless in operation, with adjustable spring and operating studs on the brake arms to compensate for wear of the brake shoes.

A. I. E. E. Midwinter Convention to Be Held at Philadelphia

ON FEB. 4 to 8, the American Institute of Electrical Engineers will hold its midwinter convention at Philadelphia. As the year 1924 marks the 40th year since the founding of the institute, a special feature of the program will be the celebration of the anniversary. Three of the founders of the institute, T. C. Martin, J. Elmer Sperry, and Elihu Thomson, will tell of the first years of the organization and John J. Carty will talk on the evolution of the institute and its accomplishments.

On the evening of Monday, Feb. 4, the Edison medal will be presented to John W. Lieb, vice president of the New York Edison Co. Mr. Lieb was in charge of operating the first Edison plant and is the 14th man to receive the medal, which is awarded for meritorious achievement in electrical science, electrical engineering or the electrical arts.

In the sessions devoted to railroads an allied industry will have the opportunity to discuss its problems under the auspices of the institute. The engineering and economic aspects of transportation will be treated by officials of the railroads and other high authorities.

Another event of importance will be the dedication of the new Moore School of Electrical Engineering. This is the first school of electrical engineering to be endowed as such, and will form part of the University of Pennsylvania.

At the technical sessions, many interesting and valuable papers will be presented.

Some of the papers to be delivered are as follows:

Variable voltage control systems as applied to elevators, by E. M. Bouton; Power plant auxiliaries and their relation to heat balance, by A. L. Penniman, Jr.; A novel alternating current voltmeter, by L. T. Wilson; Illustrated lecture on 220,000-v. transmission, by Frank G. Baum; Recent developments in kilovolt-ampere metering, by B. H. Smith; Short circuits of alternating current generators, by C. M. Luffoon; Multiple system of cooling large turbo-generators, by Donald Bratt; An experimental study of ventilation of turbo-alternators, by C. J. Fechheimer.

Headquarters will be at the Bellevue-Stratford Hotel, Broad and Walnut streets, Philadelphia.

Southern Power Companies Make Offer for Muscle Shoals

INTEREST IN THE Muscle Shoals project was revived, when on January 9th, nine of the largest power companies in the south indicated their willingness to make a new offer to the government for the use of the development. A letter from the Federal Power Commission signed by virtually all of the southern power companies operating in Alabama, Tennessee, Georgia, North and South Carolina, to Representative Harry E. Hull of Iowa contains the details of the offer which the companies are prepared to make. The following companies are participating in the offer: The Columbus Electric and Power Co.; the Yadkin River Power Co.; the Ashville Power and Light Co.; the North Carolina Electric Power Co., the Tennessee Electric Power Co.; the Memphis Power and Light Co.; the Alabama Power Co.; and the Central Georgia Power Co.

Briefly, their plan is as follows:

1. To organize a power company which shall lease under the provisions of the federal water power act, the Muscle Shoals power plant for a term of 50 yr.

2. For the power so acquired, they will pay the government approximately $100,000,000 during the 50 yr. term, including maintenance and repairs, or approximately 4 per cent on the government's investment in the project.

3. To provide at cost of production power for use in connection with the manufacture of fertilizer under such terms as Congress may decide.

4. To lease the present Sheffield steam plant at Muscle Shoals, or should the government decide to sell that property, to pay $4,500,000 for it.

5. To undertake the immediate construction of transmission lines at an estimated outlay of 10 million dollars which will make Muscle Shoals power available to the manufacturing centers of the south.

6. To lease the power at Dam No. 3 in event the government provides funds for its construction, or at the companies' own expense build the dam as a navigation and power project and operate it under the Federal water power act.

In his comments on the letter, representative Hull stated that in his opinion, the plan was the most practical solution of the problem yet advanced.

"Not only does the proposed offer," stated Mr. Hull, "provide for a payment to the government of approximately 100 million dollars during the 50 yr. period of the lease, as provided under the federal water-power act, but the interest of the farmer in the potentialities of cheap fertilizer production at Muscle Shoals is thoroughly protected by the reservation of a large block of power, provided under the plan, for such arrangements as Congress may desire to make for manufacture of fertilizer in connection with the nitrate plants. The power not so utilized is thus made available to industry throughout the entire South, from the Carolinas to Louisiana, under the protection and regulations of our established national water-power policy.

"It should be pointed out that there is nothing in this plan which would debar Mr. Ford from carrying out his often-expressed desire of doing something for the farmers by the manufacture of fertilizer at Muscle Shoals. The nitrate plants are still available to him, with the necessary power, on whatever terms Congress may decide. I want the government to encourage him or any one else, and afford every opportunity and assistance, in the solution of this most pressing problem with the farmer.

"In any disposition of Muscle Shoals I regard these conditions as fundamental: first, the maintenance of the plants as preparedness against war; second, their utilization so far as practicable in time of peace for production of fertilizer, and, third, the distribution of the power not so used to the public under regulations which will insure an adequate return on the investment in the power development.

"Last year I prepared a resolution which, if adopted, would secure these results. I shall reintroduce it to conform to conditions that now exist and will urge its adoption. I believe it will solve this whole question to the satisfaction of everyone who desires that the government and the public secure the greatest benefit from the enormous investment of public funds at Muscle Shoals."

News Notes

DAYTON-DOWD Co., of Quincy, Ill., announces the opening of consolidated sales offices at 30 North Michigan Ave., Chicago.

E. KEELER Co., Williamsport, Pa., announces the appointment of C. C. Loder as sales manager, Pittsburgh territory, with headquarters Room 609, Chamber of Commerce Building, Pittsburgh, Pa.

JOSEPH R. DARNELL, formerly associated with the Fuel Division of the U. S. Bureau of Mines and lately combustion engineer for the Sinclair Refining Co., has been appointed assistant chief engineer of the United Machine & Manufacturing Co., Canton, O.

RILEY ENGINEERING Co. of Canada, Ltd., a division of the Underfeed Stoker Co. of Canada, Ltd., Toronto, Canada, has been granted an exclusive license for the sale and manufacture of the Harrington forced blast traveling grate stoker throughout the Dominion of Canada.

NICHOLAS M. DUCHEMIN has assumed the duties of general superintendent of the West Lynn plant of the General Electric Co. following the death of William J. Lloyd on Oct. 28. This follows an announcement recently made by F. P. Cox, manager of that plant.

GOVERNOR BAXTER of Maine, who a year ago vetoed the action of the Maine Legislature in granting power rights to the Kennebec Reservoir Co., has invited those interested in the Reservoir company to a conference to be held in Boston this month, for further discussion of the plan sub-

mitted at that time. The company proposed development of water power in the Dead River and Long Falls sections into electric energy. A score or more heads of manufacturing company heads whose plants are located along the Kennebec River are interested in the proposition.

BUNDY STEAM TRAP CO. announces the appointment of R. G. Wilcox, 343 Calvert St., Baltimore, Md., as its sales representative for Baltimore and the District of Columbia.

DWIGHT P. ROBINSON & CO. has been authorized to design and construct extensive additions to the shops of the Southern Railway Co., at Birmingham, Ala. The work includes locomotive repair shops, boiler and smith shop, car repair sheds, mill shop, power plant and other buildings.

ALTERATIONS are being made to the generating station of the Haverhill (Mass.) Electric Co. which will include enlargement of the plant and equipment. Charles H. Tenney & Co., of Boston, are the engineers. The addition will be of brick, steel and tile, one story, 75 by 90 ft. and will cost about $35,000 exclusive of equipment.

NATIONAL ELECTRIC LIGHT ASSOCIATION will hold its forty-seventh convention at Atlantic City, May 19 to 23 according to an announcement made by President Walter H. Johnson following a meeting of the national executive committee held on Dec. 14. The exhibition committee announces that an exhibit, similar to the one held in 1922 at Atlantic City, will be held in connection with the convention.

FRANKLIN LIGHT AND POWER CO., of Farmington, Me., has purchased all of the power rights in the Carabasset stream at North Anson, Me., from Fred Bunker, of North Anson, and Henry Newhall, of Fairfield, Me. The new owners plan the construction of a concrete dam and the development of 3000 hp. At the present time, the Franklin company buys some power from the Central Maine Power Co. with which to supply some of its customers. It is believed that the additional power obtainable from the new project will relieve it of purchasing power outside.

Catalog Notes

IN A FOLDER recently issued, the Combustion Engineering Corporation, of New York City, describes the new Frederick multiple-retort underfeed stoker.

"EFFICIENT COMBUSTION" is the title of a folder issued by the Sanford Riley Stoker Co., of Worcester, Mass., in which the various bulletins and catalogs on Riley equipment are described.

MCCLAVE-BROOKS CO., of Scranton, Pa., has issued two more bulletins which are of a series to be placed in a loose leaf folder to make up a general catalog. Shaking and cutoff grates are described and the other bulletin covers sectional boiler fronts.

IN A PAMPHLET entitled, "Efficiency Tests of De Laval Motor Driven Pumps," the De Laval Steam Turbine Co., Trenton, N. J., publishes the results of efficiency tests upon several large units installed in municipal water works plants. In sizes ranging from 300 to 1500 hp. each, these units show overall efficiencies, including pump and motor, between 75 and 82.5 per cent, making possible highly economical pumping where the power is obtainable at a low price from central stations. The pumps themselves now show efficiencies practically equal to those of the best hydraulic turbines of similar capacities. A 20,000,000 imp. gal. per day pump at Toronto, for example, showed an efficiency of 87.2 per cent, and another pump of about the same size at Baltimore is credited with 86.9 per cent, while a 12 in. pump at Newton, Mass., designed to deliver 2,000,000 gal. per day, showed an efficiency of 83.8 per cent.

IN A FOLDER entitled "The Answer," the Power Plant Efficiency Co., of Indianapolis, Ind., has discussed its system of interlocking sectional tile baffles.

IN A BULLETIN which has been issued recently, the Girtanner Engineering Corp., of New York City, has described its line of coal and ash-handling machinery.

HANNA AIR HOISTS are described in catalog No. 14, now being distributed by the Hanna Engineering Works, of Chicago. Hoists of this type find particular application in ice plants and general industrial work.

"ATWOOD POWER PIPING MANUAL" is a bulletin issued by the Pittsburgh Valve, Foundry & Construction Co., of Pittsburgh, Pa., which presents information on piping specifications, details of fittings and some general information on piping layouts.

"MAN-POWER MULTIPLIED" is the title of a booklet describing the locomotive crane equipment of the Brown Hoisting Machinery Co., of Cleveland, Ohio. Cranes of this type are used for handling coal and other materials and are furnished in creeper type and railroad truck mountings.

BULLETIN No. 126-3 of the D'Olier Centrifugal Pump & Machine Co., of New York, describes some of the larger pumps which have recently been built by this organization. Among these are the three low lift pumps which have just been completed for the city of Detroit filtration plant.

"TURBO BLOWERS AND TURBINES" is the title of a bulletin issued by the Carling Turbine Blower Co., of Worcester, Mass., which presents the details of its new type of stoker fan. In this the radial blades have been used instead of the straight type; guide vanes are used in the fan housing so that losses due to eddies and friction are reduced.

TRADE STANDARDS adopted by the Compressed Air Society has just been published, embodying the result of extended study and research on the part of the executives and engineers associated with the members of that organization. It embraces the nomenclature and terminology relating to air compressors and their operations; a history of the development of speeds of air compressors; an explanation of capacities and pressures; instructions for the installation and care of air compressors with illustrations of devices suggested for cleaning the intake air; recommendation for the lubrication of air compressing machines and the cleaning of air receiver piping; a description of the low pressure nozzle test recommended by the Society, and a partial list of applications of compressed air. Copies may be had from the members or by addressing the Secretary of the Society, C. H. Rohrbach, 50 Church St., New York.